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INSTITUTE FOR DEFENSE ANALYSES

Integrated Product and Process Development (IPPD) Case Examples

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PREFACE

This paper documents work performed by the Institute for Defense Analyses (IDA) in partial fulfillment of the task entitled "Integrated Product and Process Development (IPPD) Implementation Support." The work was sponsored by the Office of the Director Test, Systems Engineering and Evaluation (DTSE&E).

This document compiles IPPD examples from the open literature without further analysis. The inclusion of a company, program, or process in this report does not constitute endorsement by IDA.

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SUMMARY

To help the Office of the Director Test, Systems Engineering and Evaluation (ODTSE&E) in its efforts to conduct Integrated Product and Process Development (IPPD) case studies, the Institute for Defense Analyses (IDA) searched the open literature and the World Wide Web for examples of IPPD implementation. This document summarizes these examples of IPPD implementation within the Department of Defense (DoD) program offices and defense and commercial industry. Chapter II presents examples from the defense industry. Chapter III concentrates on examples from acquisition programs in the Services. Chapter IV gives examples from commercial industry. The examples from industry—defense and commercial—are roughly grouped by industry sector.

These examples show numerous successes with various facets of IPPD implementation. Different examples use different terms to describe the basic IPPD principles, but the message is still the same—involving the customer and the right stakeholders early, focusing on the life cycle, and developing products concurrently with their related processes all contribute to producing products faster, better, and cheaper. These examples are presented here for ODTSE&E to consider as candidates to expand into case studies. Although most of this document contains summaries of other documents, some things have been liberally excerpted from other sources. We include them here so that ODTSE&E has the information readily available in one document.

I. INTRODUCTION

This document summarizes examples of Integrated Product and Process Development (IPPD) implementation within the Department of Defense (DoD) program offices and defense and commercial industry. Chapter II presents examples from the defense industry. Chapter III concentrates on examples from acquisition programs in the Services. Chapter IV gives examples from commercial industry. The examples from industry—defense and commercial—are roughly grouped by industry sector. Appendix A excerpts case studies from an Army document. Appendix C lists the references from which the examples were taken.

A. BACKGROUND

The Office of the Director Test, Systems Engineering and Evaluation (ODTSE&E) has the responsibility to support USD(A&T) implementation of the IPPD approach within the acquisition community. To this end—

- IPPD “Guiding Principles” have been incorporated in DoDD 5000.1 and DoD 5000.2-R.
- An IPPD Guide was published on 5 February 1996.
- A survey was conducted on IPPD/IPT implementation in both government and industry.
- An IPPD handbook was released through the DTSE&E home page in July 1998.
- IPPD concepts are being incorporated into existing courses and an IPPD course is being developed by the Defense Acquisition University (DAU).
- A decision was made to explore IPPD case studies.

B. IDA APPROACH

To help ODTSE&E in its efforts to conduct IPPD case studies, IDA searched the open literature and the World Wide Web for examples of IPPD implementation. We include in this report examples for ODTSE&E to consider expanding into case studies. Although most of this document contains summaries of other documents, some things

have been liberally excerpted from other sources. For example, Appendix A is taken directly from an Army document referenced in Appendix C. We include it here so that ODTSE&E has the information readily available in one document.

C. ELEMENTS OF A GOOD CASE STUDY

A case study generally consists of a problem statement, the solution tried or decision made, and the outcome. Business change drivers create a problem that affects certain business processes. The solution to these problems requires a strategy and a goal. Depending on the strategy and tactics chosen, an outcome is determined.

A good case study is written at an operational level and is designed to enable decision makers to make their own decisions relative to their company's or acquisition program's situation and experience. The outcome of a case study can be either good or bad—both successes and failures constitute a good case base. If a company or acquisition program adopts a certain strategy, technology, or practice and, as a result, problems ensue, this outcome is important for decision makers to know.

II. DEFENSE INDUSTRY EXAMPLES

This chapter describes IPPD implementation examples from defense companies—either in general across the company or for specific defense programs.

A. MOTOROLA—GOVERNMENT AND SYSTEMS TECHNOLOGY GROUP

During the 1970s, Motorola faced increased competition and threats to its share in various markets. Since the 1980s, however, Motorola has pursued new strategies to improve product quality, including a commitment to the six sigma level (3.4 defects per million). In 1988, the company was rewarded for its efforts as the first recipient of the Malcolm Baldrige National Quality Award. Moreover, the company revenues have increased from \$5 billion (1983) to \$17 billion (1993). Furthermore,

Motorola has become much admired as a role model for American business. Its excellence lies in good part in a deeply bred ability to continually move out along the curve of innovation, to invent new, related applications of technology as fast as older ones become everyday, commodity-type products.¹

More recently, Motorola has been attempting to adapt its quality improvement approaches to the process of product development by setting a goal for a 10-fold reduction in the product development cycle. Central to this effort is Concurrent Product Development (CPD). Motorola's Government and Systems Technology Group (GSTG), which is tasked with the development and production of electronic components and systems primarily for government, has adopted varying methods in its approach to CPD. Such methods include Product Development Assessment (PDA), teaming, training, organization and project management, methods and tools, measurement and reward systems, supplier involvement, and a consistent product development process.

The PDA represents a year-long benchmarking effort during which 18 companies are analyzed with regard to such issues as cycle time reduction, new product development

¹ "Motorola Government and Systems Technology Group (GSTG)," Case Study Appendix, *Concurrent Engineering Effectiveness: Integrating Product Development Across Organizations*, Mitchell Fleischer and Jeffrey K. Liker, Hanser Gardner Publications, Cincinnati, OH, 1997, p. 432.

processes, robust design and training, electronic networks and interfaces, and empowerment. Motorola uses two types of teaming: empowered project teams and ad hoc problem-solving teams. Training is emphasized throughout Motorola, but GSTG in particular operates a Concurrent Engineering Training Program, which is designed around the focus areas of the PDA and includes training on various tools. The GSTG structure is a matrix in which employees fit within a functional structure under a functional manager but may work on specific projects assigned to that functional group. Motorola has developed its own tool, Design for Total Unit Production Cost (DTUPC), but also uses other methods and tools associated with concurrent engineering. Examples include Statistical Process Control (SPC), Design for Manufacturing (DFM), Design for Assembly (DFA), Design of Experiments (DOE), and Robust Design.

The measurement or collection and documentation of data as an indicator of problems or success is very important to Motorola and, indeed, a system has been established to reward employees/teams for performance. The company established the Early Supplier Involvement program to involve suppliers early in concept development, allow for single source for complex parts, identify critical parameters for supplier processes, and establish general price agreements. By implementing efforts such as this, Motorola has decreased its supplier numbers from 6,000 to 600 since the early 1980s.

Finally, Motorola has broken the product development process into a six-phase task for each of the functional areas, but teams may adapt these phases to a specific project's needs. The company has a series of checklists that teams must complete to ensure that they adhere to the established phases.

B. TEXAS INSTRUMENTS—GEN-X DEVELOPMENT PROJECT

The Naval Air Systems Command GEN-X decoy project was established to provide an expendable decoy to be used to assist in protecting tactical aircraft. The decoy would draw the attention of the radar systems of enemy missiles, thus protecting the aircraft from surface-to-air and air-to-air guided radar systems. The Defense Systems and Electronics Group (DSEG) of Texas Instruments became involved with the GEN-X project in September 1987, when it was contracted to design and test a decoy. This original decoy was determined to be too heavy and costly, so DSEG made an ambitious second bid to design a decoy that would decrease cost by a factor of four. DSEG's second attempt at the design and test of the GEN-X decoy began in May 1992 and

included teaming, design for manufacturability, and the use of computer-aided design (CAD) systems.

Traditionally, DSEG has had a very strong functionally based organizational structure with project leaders having little authority over their team members. For the design of the GEN-X, however, DSEG wanted to use a more empowered, team-based structure, but the functionally based culture proved entrenched. Team members were pulled only on a part-time basis, and the project manager was only able to collocate a core set of individuals in the same building for most of the project duration. In all, the team had approximately 110 members that were divided among the module, antenna, and an airframe group. From these basic teams, subteams were also formed from time to time. Coordination and communication among teams and team members proved a problem since schedules did not readily permit meetings among all team members.

In its effort to design for manufacturability and reduce the cost of the end decoy, the GEN-X team recognized early on the importance of addressing manufacturing issues during the product design and development phase. Manufacturing engineers and hourly employees collaborated in team efforts, working concurrently with product design to fine-tune the details of the manufacturing process and estimate the costs of various manufacturing procedures. This interaction allowed the team to compare the manufacturing costs of various product designs and, consequently, to reduce the number of soldered joints from 49 to 6 (reducing the risk for defects and their resulting costs). The team was also able to identify and design an internal module clamp that made production simpler. In addition, a supplier engineer participated in the process, gaining knowledge that enabled the supplier to design a battery that significantly reduced the weight of the overall decoy.

DSEG had at its disposal a design center that assisted in providing automated design support and acted as an interface for the smooth flow of data among the various functional groups. ProEngineer was the main CAD tool used to integrate drafting, design, analysis, and stereo lithography. The Initial Graphics Exchange Specification (IGES) was used to send and receive design information from customers and suppliers.

Even when only interim results were available, the GEN-X project could claim the following accomplishments:

- 30 percent decrease in development cycle time (2.5 years)
- 90 percent of design completed within the first 2 years

- Factor of 5 reduction in cycle time
- Factor of 4 reduction in cost
- 30 percent decrease in design changes
- 90 percent of design changed to bring down cost
- Number of airframe parts cut in half
- On-time delivery of prototypes and early trial devices
- Achievement of 4.7 sigma as predicted by manufacturing simulation

After the GEN-X project, Texas Instruments developed its Integrated Product Development (IPD) program, which has been applied to all DSEG design projects since October 1992.

C. NEWPORT NEWS SHIPBUILDING—SEAWOLF NUCLEAR SUBMARINE

In developing the Seawolf, the new class of nuclear attack submarines to follow on the 1960s Los Angeles class, the U.S. Navy was faced with starting virtually from scratch. Many existing parts and systems would not address the increased performance requirements set for this new submarine class. To meet this challenge, the Navy enhanced performance requirements and, departing from the norm, contractually required a unique working arrangement among two competitors. Indeed, Newport News Shipbuilding (NNS) and the Electric Boat (EB) Division of General Dynamics were required to work together on the design and construction of the Seawolf. EB took the lead for the propulsion (aft) section of the submarine, while NNS focused on the living and operations (forward) section.

The two companies used a number of methods, tools, and approaches, including contributing technologies and teams. NNS, on the one hand, used its own VIVID modeling system, which is based on constructive solid geometry, to allow it to produce large models and send sectional and construction drawings of its section, rather than individual parts. It used CADAM for modeling structural parts and machinery components. This data could then be imported into VIVID for the creation of manufacturing drawings. EB, on the other hand, used its own PIPER system and ComputerVision commercial CAD system, which does not provide a ready interface with CADAM.

Because NNS was tasked to work with EB in the design and construction of this submarine class, the direct exchange of data was a particularly critical issue. Recognizing

this fact, the Navy, NNS, and EB worked to make the U.S. standard for the exchange of geometric product data between different CAD systems—Initial Graphics Exchange Specification (IGES)—capable of fulfilling the program's CAD data exchange needs. The use of this standard proved to be particularly advantageous because it allowed for the exchange of data throughout the life of the program, despite numerous software changes.

Traditionally, NNS was organized functionally with product teams divided among the hull, electrical, piping, and mechanical systems. Each team designed for its own system with little thought to impacts on other systems, while manufacturing planning typically did not begin until drawings and design were well under way. Under the Seawolf program, NNS established "Space Kings" and gave them responsibility for coordinating space allocation within a specific area of the submarine. In addition, manufacturing planners would analyze assembly sequences using VIVID and report problems and suggestions to the design teams.

Aside from using design teams, NNS used two other types of teaming approaches:

- Quality Improvement Teams represented a more formal structure with a seven-step process for identifying problems.
- Task teams were a less formal mechanism for combining design and manufacturing staff to address specific problems.

Each functional design group used its own design process, but overall coordination was ultimately made possible through the universal use of VIVID and the master schedule. Manufacturing became involved at a noticeably earlier stage in the design process. VIVID allowed the construction and assembly processes to be explored and analyzed in an electronic format, which in turn allowed the generation of assembly instruction drawings. The detailed electronic representation of the Seawolf design also allowed servicing access requirements to be addressed from an early stage. Indeed, Seawolf's success can be largely attributed to the use of a single comprehensive model.

NNS's use of VIVID in the early stages of component design aided in the integration of components down the road. The Seawolf program demonstrated the importance of accomplishing work in different functional areas within the same period in order to avoid unnecessary delays.

D. BOEING AEROSPACE CORPORATION

1. Ballistic Systems Division—Developmental Operations Program

The Ballistic Systems Division of Boeing Aerospace Corporation has a program called “Developmental Operations,” which has as its goal to simplify the practices and processes of development. Under this program, simplified process techniques have been adopted by a multifunctional development team, with the following results:

- The time spent on the analysis of design dropped from 2 weeks to 38 minutes.
- The average number of engineering changes per drawing dropped from 15 or 20 to 1, in at least one case.
- Because critical inspection features were directly marked on the drawings, the ratio of shop floor inspection to direct labor dropped from 1:15 to 1:50.
- Seventy percent of needed parts were in the factory within 5 days.
- Lead times decreased 30 percent.

2. Boeing Defense and Space Group—Corinth

Boeing Defense and Space Group-Corinth (BD&SG-C) is a wholly owned subsidiary of the Boeing Company that was started in the late 1980s. By 1993, it had already been named the Boeing Center of Excellence. From the beginning, BD&SG-C focused on implementing innovative management methods. Its central concept is the self-directed team, which is organized around whole products and processes.

The self-directed team is based on sociotechnical work systems. Sociotechnical work systems provide employees with job enrichment and enlargement opportunities by grouping them in teams that are given responsibility for all activities related to a unit of production. Teams form and disband as necessary, often with new members joining or leaving. Generally, teams include 3 to 16 members who assume responsibility for specific technical tasks, but also serve in various team leadership roles on a rotating basis. Each team develops an Oregon Productivity matrix that documents the team’s relevant performance factors, objectives, and results.

BD&SG-C also has a highly developed six-level training system, the Pay for Knowledge system, which links an employee’s knowledge/skill level to pay rates. Each level consists of training and the employee’s ability to prove the mastery of a certain skill

level. All employees are expected to pass through all six levels in about 3 years, receiving salary or wage increases as they progress to the team rate.

BD&SG-C originally concentrated on the military product sector. However, by 1991, its focus had reversed—its work was 85 percent commercial and 15 percent military. In 1993, however, the percentage of military work increased to 60 percent. The use of self-directed teams seems to have allowed for the flexibility necessary to integrate military work into the commercial side and vice versa as necessary. The wisdom of its flexibility was confirmed by the following developments:

- Low cost, high quality and on-time performance caused BD&SG-C to be named Boeing's Center of Excellence for electronics.
- An employee attitude survey found BD&SG-C employees to be more satisfied compared with those throughout Boeing as a whole.
- Received recognition for having a reject rate of .00029 for the on-time delivery of 100,000 wire bundles.

E. NORTHROP GRUMMAN CORPORATION

For its IPPD implementation, Northrop Grumman Corporation (NGC) has developed a suite of tools for Design for Manufacturing/Assembly (DFMA) and Variability Reduction (VR).

Integrated Product Development (IPD) Data Sheets are controlled drawings at the assembly level that depict the interrelations of detailed parts, tooling, and assembly sequences for each cost center. They include the datums of detail parts and the tolerance requirements of part features and tooling part locators. They also include key characteristics at the assembly level that are then flowed down to the detail part level.

Geometric Dimensioning & Tolerancing (GD&T) is an internationally recognized engineering drawing language that specifies tolerance/dimensional requirements with respect to actual function and relationship of part features. NGC has provided extensive GD&T training to IPD team members and suppliers.

Statistical Process Control (SPC) provides data to measure the capability of critical processes and/or key characteristics to produce quality parts within specified tolerance bands and to control process shifts and spreads. Successful SPC applications on close tolerance holes and countersinking have resulted in significant defect reduction.

Key Characteristics (KC) are designated to identify those part or assembly features/interfaces for which variation from nominal results in the greatest loss. SPC measurements are focused on key characteristics to minimize variation, ensure capable processes, and reduce unnecessary inspection requirements.

Variation Simulation Analysis (VSA) is an assembly simulation model in which detail part and tool tolerances are compiled to predict conformance to geometric requirements to include out-of-specification conditions. VSA is proprietary software requiring seat licenses, and it operates in a three-dimensional (3-D) environment. It is being used on selected aircraft programs.

NGC's experience shows that the combination of these DFMA/VR tools with 3-D design and IPD implementation has resulted in—

- Improved parts fit
- Net trimming before assembly
- Reduced shimming
- Reduced assembly hours/cost
- Reduced cycle time

F. GRUMMAN CORPORATION

In staffing integrated product teams (IPTs) for the C-17, Grumman Corporation had to solve various problems, as exemplified below.

Problem—Inexperienced personnel received inefficient direction because disciplines were dispersed throughout various teams.

Solution—Teams were consolidated to minimize the number of disciplines with one or two members. Inexperienced personnel were placed on the larger teams where group leaders and other lead people made efforts to maintain contact with them.

Problem—No one person knew or understood the overall control surface because teams rotated to all surfaces to work on similar tasks.

Solution—Key members of the Cover Team were assigned to each control surface and given responsibility for the overall coordination of tasks relating to that surface.

Problem—Some tasks had to be tediously repeated.

Solution—Team members were required to communicate with other teams and to participate in the design and analysis of interfacing structure in addition to their primary tasks.

G. AEROJET ORDNANCE

Poor production quality and nonconforming products were a problem for the government-owned/contractor-operated (GOCO) plants making the Area Denial Artillery Munition (ADAM) mine for the Army. Nineteen out of 25 lots were rejected (40,000 rounds per lot). A joint team of government and industry tried—without success—to find the cause of the problem. Although Aerojet Ordnance had not developed this product, it was called in to apply Taguchi experiments to the testing. Aerojet took 3 months to prepare for and conduct experiments in order to identify the critical parameters. It identified 13 controllable factors and set three different levels for each factor (all except one were within tolerance). Aerojet fired six rounds for each experiment. It identified four factors of greatest improvement and determined how building the round with those factors at optimum levels would provide rounds virtually 100 percent in conformance.

These predictions were validated in field testing. When the parameters identified in the experiments were used, 54 rounds were produced and tested without a failure. This was the first time in the history of the product that a 100 percent yield had been observed over a reasonable time. Another 54 rounds were produced using a parameter setting for which the experiments predicted a yield of 50 percent. Twenty-seven of the rounds failed the test. Production lines are now working to capacity, building good products. There have been no reported problems in 8 months.

H. INGALLS SHIPBUILDING

1. Scheduling and Encumbering Resources via Simulation

Ingalls Shipbuilding has implemented discrete event simulation models to perform the tracking and decision-making necessary on the monthly resource requirements for its production facility. Ingalls takes the data to update the simulation models from the information on work orders that represent the next 5 years of production. The simulation models access this data and determine the skills hiring and machine requirements necessary for the next month of production. A schedule is also generated to ensure the coordination of personnel and material resources throughout this 1-month

period. Ingalls has also been investigating the transference of these simulation models to determine and manage resources, skilled labor, and scheduling at a lower than facility level.

2. CAD Data Model Interference Checking and Supporting Numerical Control Tools

When dealing with modular design, it is essential to resolve as soon as possible the interference caused when subsystems and components are joined. The goal is to have as little interference as possible once a ship is ready to be "floated." Ingalls Shipbuilding first introduced the use of virtual reality simulation to address issues of interference in its SA'AR 5 Corvette Program, which dealt with the construction of a major warship. The benefit of virtual reality simulation is that it allows the designers to address problems with interference in the shop, rather than on the "floated" ship, saving time and money in the long run. A full CAD data model is used to design and construct the ship, as well as to provide support throughout the ship's 20- to 30-year lifecycle. Through the CAD data model, one has ready access to the ship's components, changes made to the original design, and a set of current 3-D CAD models for the ship and its subsystems.

3. Measuring Increased Productivity

Ingalls Shipbuilding has introduced a method for determining the efficiency and contributions of the full 3-D CAD data model. For quantitative analysis, Ingalls compares the number of bills or work instructions started/completed and the number of engineering change notices that have been made to remedy problem areas. For qualitative analysis, Ingalls examines how each functional area's budgets and timetables are affected. The benefit is projected to be a decrease in assembly time.

I. WESTINGHOUSE ELECTRONICS SYSTEMS GROUP-MODAR PRODUCT DEVELOPMENT

The Westinghouse Electronics Systems Group's development of the Modular Radar (MODAR) program represents an example of adapting a militarily developed radar to commercial applications. In designing and developing the MODAR, the objectives were to produce a new radio with a rapid development cycle, lower development investment, decrease production costs, and increase product reliability. The project was organized into IPPD teams to give product ownership to the lowest possible level. For each module of the radar, there was a team whose members were drawn from all

functional areas. A designated team leader assumed responsibility for the integration of all functional areas and any subteam efforts. Some important results of the MODAR project are as follows:

- Reduced the prototype development cycle by 50 percent from 12 to 5 months
- Reduced the prototype development cost by 50 percent
- Integrated and harmonized hardware within 2 rather than 8 weeks
- Demonstrated functional radar in first flight test just 22 weeks after program start
- Reduced production material costs by 75 percent by focusing on material specifications and quality
- Reduced assembly and test times by at least 90 percent

In sum, MODAR is more reliable and 80 percent less costly to produce.

III. DEFENSE PROGRAM OFFICE EXAMPLES

This chapter summarizes IPPD examples from various acquisition programs in the Services.

A. ARMY PROGRAMS

1. UH-60 Blackhawk Helicopter

The UH-60 Blackhawk Helicopter integrated product team (IPT) was formed to manage the 2-year integration and qualification phase of the UH-60. The IPT consisted of an unusually large number of long-term members with diverse skills and specialties as well as a wide range of expected customer activities. Membership included the Army medical community; the U.S. Army Aviation Center (USAAVNC); and engineering, quality, logistics, test and evaluation, avionics, human factors, Department of the Army (DA), and DoD personnel as well as interfacing contractors and subcontractors.

To date, use of IPT methodology has produced the following:

- Shorter time to create and coordinate the Request for Proposal (RFP)
- More rapid resolution of problems
- Earlier consensus on decision processes
- Rapid turnaround time for reviewing competitive source selection packages and technical data
- Fewer deliverables and concurrent review of deliverables by all disciplines
- Shortened schedules for task and subtask completion
- Reduced IPT-contractor coordination time gained through use of electronic minutes of meetings.

POC: UH-60 Blackhawk PMO, Mr. Larry Johnston (314) 263-17021

2. RAH-66 Comanche Helicopter

Program reviews included in the RAH-66 Comanche Helicopter Integrated Master Plan/Integrated Master Schedule (IMP/IMS) use the IPPM methodology. These reviews

provide the foundation to establish compliance with system requirements. The reviews range from technical system and segment level reviews to a series of informal technical reviews concerned with a specific segment or task element of the Work Breakdown Structure (WBS) that involves only a few government and contractor personnel.

The technical reviews include:

- Software Specification Review (SSR)
- Preliminary Design Review (PDR)
- Critical Design Review (CDR)
- Interim Progress Review (IPR)
- Test Readiness Review (TRR)
- First Flight Design Review (FFDR)

All reviews are held between the prime contractor (Boeing/Sikorsky) and subcontractors or vendors as necessary.

The periodic program and hardware reviews conducted with the subcontractors and vendors supplying complex hardware and software include:

- Costs and schedule status
- Vendor plans for aircraft equipment, software, test equipment, related testing and supportability
- Technical performance and risk assessments
- Status of change approval and implementation
- Hardware and facility inspections and demonstrations
- Problem areas, alternatives, proposed solutions, and potential impacts

Lessons learned while converting to the IPT organizational methodology are as follows:

- IPT philosophy takes leadership from the top
- Efforts to improve team communications/integration need to be continuous
 - The “I” in IPT is Integrated, not Independent
 - Vertical and horizontal integration is critical
 - Business (finance/contracts) needs to be closely integrated
- Functionals must clearly understand their roles and responsibilities

- All stakeholders who have an interest in the outcome should be involved
 - Program Management Office (PMO), contractors, suppliers, users, Defense Contract Management Command (DCMC), and Office of the Secretary of Defense (OSD)
- Training to function as a team is paramount.
 - Empowerment means enabling, not stonewalling
- An integrated network of communications/software tools is mandatory
- IPT goals and objectives must be established and tracked
 - Ensure all team members participate in decisions
 - Develop meaningful team metrics
- There is no substitute for open dialogue
 - Communicate, communicate, communicate

POC: RAH-66 Comanche PMO, Ms. Dayne Ventura (314) 263-2510

3. Enhanced Fiber Optic Guided Missile

The Program Manager (PM) for the Enhanced Fiber Optic Guided Missile (EFOGM) locked down the second phase of its design effort in December 1996. This was possible because of an IPPD-conducted design review held in September 1996. The PM purposely used the prime contractor's format to save time and dollars during the review.

Government and contractor members worked side by side on a daily basis. Formal reviews, when they were held, constituted management and decision updates of the status of mutually shared progress.

The result of using the IPT methodology is illustrated by comparing the previous Non-Line-of-Sight Full Scale Development (NLOS FSD) effort in which a total of 26 months (Dec 88 - Jan 90) was consumed and the PDR was still incomplete. IPPD allowed a schedule savings of approximately 15 months because of close government and contractor interaction created by the process. Unfortunately, the IPTs tended to focus more on processes than events, and individual IPTs tended to live forever with no measure of success. One of the lessons learned from the EFOGM program was to have IPTs be event oriented rather than focusing solely on process.

POC: EFOGM PMO, Mr. Douglas Curtis Seay (205) 876-8520

4. AH-64D Longbow Apache

The Army initiated planning for the AH-64D Longbow Apache's Milestone III Decision Review (MDR III) using guidance in the DoD Directive 5000 series' acquisition requirements dated February 1991. Prior to the scheduled review, however, an Army Assistant Secretary, Research, Development, and Acquisition, formed an MS III Ad-Hoc Working Group (AHWG) and issued a Letter of Instruction (LOI) calling for AHWG participation in the MDR III process. The LOI identified representatives from the ASARC principals, the DA staff, designated Army agencies, the Longbow Apache PMO; Longbow Hellfire PMO; Program Executive Officer (PEO), Aviation; and the PEO, Tactical Missiles. The PEO, Aviation, was designated as the Chairman of the AHWG. The AHWG was tasked to review and coordinate guidance with their respective organizations.

Subsequently, at the direction of OSD, the AHWG was expanded to include representation from the OSD staff and Defense Acquisition Board (DAB) principal. The AHWG was renamed the Longbow MS III IPT and an OSD co-chairman was designated. The OSD members were integrated into the previously established meeting process. Joint participation by DA and OSD staff representatives utilizing IPT and Overarching IPT (OIPT) methodology greatly facilitated and accelerated the MDR III preparation process:

- Accelerated milestone documentation review process
- Eliminated a formal Army Systems Acquisition Review Council (ASARC) and separate OSD document review
- Eliminated a formal DAB review
- Resulted in a favorable MDR III decision for production

POC: AH-64D Longbow Apache PMO, Ms. Shirley Standish (314) 263-3565

5. Patriot Advanced Capability-3 (PAC-3) Missile System

In the past, a Production Readiness Review (PRR) team consisted of select government reviewers who might not have been involved with the program review. Their knowledge of the technologies being applied or program management issues was limited. The PM endorsed a novel approach to the PRR for the PAC-3 Program. The PAC-3 was already engaged in IPTs as the PRR approached. It was a good time to redefine the old PRR culture and make it a part of the streamlined acquisition process.

Senior personnel of MICOM and Lockheed Martin Vought Systems (LMVS), the prime contractor, co-led each team. The PRR team co-leaders drew the team membership from the IPTs. The co-leaders tailored the composition of the team to each site. Each team had a one-to-one ratio (almost) of government and contractor members. The co-leaders usually paired a government employee with an LMVS employee to review a functional area, e.g., quality or design.

The teams visited 15 production sites. At the end of every visit, the team members presented a briefing to the personnel at the site. The PRR team recorded and sent written concerns to the responsible IPT for resolution.

Before the PRR visits started, the co-leaders provided orientation training in Dallas, TX, and Huntsville, AL. They distributed to all team members a list of potential questions applicable to assessing production readiness. With the assistance of the University of Alabama, Huntsville, AL, they provided the team members Internet access to a database that identified the membership, travel arrangements, meeting schedules, concerns, and concerns tracking.

POC: MICOM, Mr. Phil Hodges (205) 313-6540

IPT Organization

An example of the integrated product and process structure is the Patriot PAC-3 Missile program. The primary IPTs represent the major products and the major processes required for a successful acquisition of those products.

Product IPTs	Process IPTs
Missile	Performance and Simulation
Seeker	Test and Evaluation
Command and Launch System	Production

6. Close Combat Tactical Trainer

The Close Combat Tactical Trainer (CCTT) IPTs have been structured to include the user community to the greatest extent possible. Two representatives of TRADOC were stationed at the Integrated Development Facility to participate as full members of the IPTs. They were given access to all information shared among the teams and were expected to share their perspective on all issues discussed. Users also participated in the PDRs and CDRs. Therefore, design details could be communicated to TRADOC

representatives who had not had the benefit of extended participation on the IPTs. Additionally, users participated in a spiral software development effort. The spiral approach to software development calls for incremental development of increasingly complex software functionality until the full requirement is met. As each level of increasing functionality became available for testing, teams of experienced soldiers were invited to run exercises on the newly integrated software and provide the contractor with direct feedback on the success of the simulation effort.

This level of user involvement has been both a benefit and a challenge for the program. The users have challenged the program by increasing their requirements as they have become more aware of the design possibilities. The program office believes, however, that the benefits—increased understanding of the requirements early in the program and increased user acceptance of the design as a result of their early and continued user participation—has more than compensated for the challenges.

Both COL Shiflett and Mr. Edwards noted that, on large complex software integration efforts such as the CCTT program, collocation of development team members was critical for program success. The daily face-to-face interaction that allowed nearly real-time solutions to design problems proved to be invaluable for the successful completion of the program. This collocation of team members relies on the interpersonal skills of all team members and enhances the benefits that can be achieved through the chance opportunities that are created when team members interact on a frequent—often daily—basis. They both warned, however, that the increased interaction caused by this collocation also increased costs in terms of personnel resource requirements. For this reason, both questioned the utility of collocation of team members on programs where either the interfaces between program segments is well defined or the size of the program does not warrant the expense.

POC: Mr. Mike Edwards (407) 384-3612

7. Sense and Destroy Armor Project

The single most important document in the entire IPPM/IPT process for the Sense and Destroy Armor (SADARM) Project is the charter. The charter is the document that defines the purpose, application, mission, roles, and concept of operation. The charter should—

- Be a manageable document. It must contain the essential elements but it should avoid endless lists of individuals who are always subject to change.

- Define the relationships and include all of the players—government and contractor—as well as other government agencies.
- Ensure that all involved have the same understanding of *empowerment*.
- Define the actions required when a dispute cannot be settled at the functional team level and outline the follow-up procedures needed to elevate the unresolved issue for resolution.

POC: Mr. James Pritchard, (973) 724-4908

8. Abrams Tank System Project

The Abrams Tank System Project's PM office feels that an IPT member should come to the meeting with the authority to commit his/her respective office to a decision. Too many times, someone has reversed decisions in a higher position at a much later date/meeting. This is very time-consuming, nonproductive, and costly to the program as well as coordinating offices.

The Abrams PM office wants the IPT members to do one of several things:

- Come to the meeting with the authority from the parent office to commit the office to a specific decision.
- Indicate that they do not have complete authority and immediately raise the issue to the next higher authority and get their position. Then, return with a concurrence, nonconcurrence, or an alternative position.
- Ask for a replacement member who is empowered to make decisions for that office. (This would be the exception rather than the rule.)

It is not the objective of the Abrams PM office to make other members bend to the PM's position; rather, it is to make sure that decisions are made in a timely manner and not reversed at a later date.

POC: Mr. David M. Latson (313) 574-6858

9. Single Channel Ground and Airborne System (SINCGARS)

The Tactical Radio Communication PM formed the Single Channel Ground and Airborne System (SINCGARS) IPT and assigned an IPT leader to develop a new acquisition strategy for the FY97 radio production contract. The objective of the IPT was to analyze the current acquisition strategy that apportioned radio production quantities between "leader and follower" producers and explore an alternate acquisition strategy that

could yield production cost savings. IPT membership included representation from the user, test, developer, and maintainer communities. The IPT investigated and analyzed the various issues involved but was unable to reach a consensus on a single “best acquisition strategy.” With further team deliberations, the rationale for alternate acquisition strategies was developed and presented to the PM for a decision.

POC: Mr. Richard Snyder (908) 427-3023

10. Standard Missile-3

While most programs are organized around the WBS or a combined structure, the Standard Missile-3 (SM-3) program has an IPT structure organized according to traditional processes. This organization is intended to optimize existing contractor infrastructure without disrupting the program. Care must be taken, however, when using process-oriented IPTs in that their single-function nature does not end up recreating the traditional “stovepipe” bureaucracies. The team should include all concerned stakeholders, and its goals should be closely linked with the goals of the other teams and the project as a whole.

11. Army Missile Command IPPD Internet Tools

The Army Missile IPPD team at Redstone Arsenal is organizing a set of applications for performing IPPD via the Internet. The following are some of the applications currently available:

- A rolling calendar that provides teamwide coordination with hypertext links
- An action item database that provides a clear picture of responsibilities and task interrelationships, real-time task status, a multiple parameter search engine, and automatic e-mail message generation to the responsible individual when a task is assigned
- A discussion group area (similar to an Internet bulletin board) that functions as a virtual meeting area where people can be remotely located and not simultaneously present at different times
- A meeting minutes database that provides everyone with access to meeting minutes and contains a search engine for locating specific topics
- An IPT organizational/hierarchical database that—
 - Displays the current IPT hierarchy

- Provides access to team charters, missions, schedules, meeting minutes, key deliverables, etc.
- Provides a built-in e-mail capability
- Provides team member information such as skills, resumes, and photos
- A CAD drawing database capable of reading drawing data sets from the majority of available CAD programs with a “red-line” review comments feature
- A technical document library that allows documents to be stored in text or graphic form, retrieved across platforms, and researched using an advanced search engine
- A workflow management tool for timely and intelligent routing and distribution of documents with attachments

Source: <http://ippd.redstone.army.mil/mippd/>

B. AIR FORCE PROGRAMS

1. F-15 Team Eagle

A key factor in the F-15 Team Eagle's success is the team of contractors, vendors, and suppliers that have designed, supported, and redesigned the F-15 throughout its lifetime. The prime contractor for the F-15 is McDonnell Douglas Aerospace-East (MDA-East), located in St. Louis Missouri. MDA-East is working with several other significant contractors: Northrop/Grumman for electronic warning systems and test equipment, Pratt & Whitney for engines, Loral for avionics subsystems, Hughes for the radar, and Honeywell and Litton with navigation systems. The System Program Office (SPO) believes very strongly that in order to survive the severe cuts in funding and manpower experienced everywhere, the entire F-15 Team (the U.S. Government, the warfighter, industry, educational institutions) must work closely together to keep the jet flying. Consequently, industry has become an active and recognized member of the SPO's IPT teams. This membership is key to recognizing and acting on heretofore untapped resources and opportunities that must be exploited to keep the Eagle viable in today's environment. Continued nurturing of the SPO/Contractor relationship will hopefully develop improved means and processes for procuring required services and equipment. Certainly, the existing system is much too oversight intensive, resulting in high costs to manage and field a system both in respect to time and funding. Improved

relationships with our contractors will only serve to strengthen our already outstanding ability to keep the jet flying.

As mentioned earlier, the F-15 is made up of numerous subsystems, many of which have common applications with other weapons platforms. These common items or materials are often managed by a centralized product office as opposed to being managed by each weapons platform based on unique requirements. The centralized management can more efficiently use the resources and take advantage of economies of scale.

These product-oriented organizations are referred to as Materiel Group Managers (MGMs) and Product Group Managers (PGMs)—examples of which are engines, landing gear, tires, and fuels. Because of the wide dispersion of workload throughout AFMC, virtually every air logistics center and product center plays a major role in the modernization, supply, and support of the F-15. The MGMs and PGMs are obviously important members of Team Eagle—F-15s do not fly nearly as long or land as well if they do not have engines, fuel, or tires.

As the single manager, the F-15 SPO must stay in touch with all the systems and products associated with continued support of the Eagle. The SPO's main forum for discussion of these issues is the semi-annual System Supportability Review (SSR). In this forum, PGMs and MGMs are invited to discuss any problems experienced on their programs where SPO involvement or knowledge is required. In many cases, the SPO can communicate these issues to higher headquarters more effectively than the MGM or PGM. Therefore, it is extremely important that both the MGM/PGM and SPO are telling the same story as to the health of a particular system or project. Forums with high levels of attention to which the SPO has access include the Weapon System Performance Assessment Review and the Combat Operational Readiness Review, each given yearly.

Modernization efforts located at other product centers provide new capabilities to the F-15. For example, the Electronics System Center provides the latest mission planning capability and electronic warfare, the Space & Missile Systems Center provides the global positioning system, and the Human Systems Center provides upgraded aircrew equipment capabilities.

In short, MGMs and PGMs play a very important role in keeping the Eagle flying everyday. Continued team interaction and communication is fundamental in keeping this capability going strong. The F-15 SPO is aggressively pursuing enhanced partnerships and improved communications as integrated product development (IPD) continues to

grow. The Arnold Engineering Development Center (AEDC) continues in its partnership with the Air Force and the National Aeronautics and Space Administration (NASA) to test engines in their test cell facilities.

Also participating are the many private and government laboratories and universities that play an important role in F-15 supportability. These organizations work on the leading edge of technology that is so critical to the success of an electric jet such as the F-15. As older technologies become obsolete, newer technology applications become critical in order to ensure continued operational capability of the jet. One vehicle for staying abreast of the emerging technologies is the technology planning IPT, or TPIPT. The TPIPT briefs program offices on a regular basis to either gain support for a research effort or gain insight from the SPO about new problems. This process is healthy for all involved; it now includes the warfighter, who supports those technologies that bridge gaps in the users mission area plans.

Other virtual team members include the Air Force Flight Test Center, AEDC, and the Air Force Development Test Center.

Source: <http://eaglenet.robins.af.mil/org/TE.htm>

C. NAVY PROGRAMS

1. F/A-18 Compensation

The F/A-18 Program Team rewards its members based on competency and the accomplishment of team-related objectives. Team-related work objectives carry the most weight. Generic factors for team performance are listed in Table III-1.

Table III-1. F/A-18 Team Performance Work Plan Objectives

For Team Member	For Team Leader
<ul style="list-style-type: none"> • Meets team deadlines with quality product • Keeps team informed • Committed to the team and team goals • Respects programmatic issues • Provides competency expertise 	<ul style="list-style-type: none"> • Meets/under budget • Logical, clear, concise task delegation • Encourages innovation • Uses team effectively in decision making • Meets team deadlines • Timely annual performance inputs

Extracted from the F/A-18 Program Team (PMA265) Program Operating Guide, 15 November 1996.

2. Landing Platform Dock 17

a. Training

To break with traditional ship design methods and to design a new ship in a shorter time frame with a minimum number of later-phase changes, the Landing Platform Dock (LPD) 17 program manager decided that extensive IPPD training was required. The LPD 17 program first conducted IPPD training as a government team and then with the major subcontractors' team (i.e., Avondale, Hughes, Bath, Intergraph). This training included team building skills as well as IPPD principles. Key to the success of the program's training methods was the program manager's commitment to completing this training before the start of any design activity.

b. Collocation

The LPD 17 program office had five shipbuilders collocated with it during the ship's contract design and specification development stage before Milestone II and RFP issuance. This collocation aided in the producibility of the contract design package as well as the ship specification.

The program office was collocated to the site of the chosen prime contractor (Avondale) along with representatives from the industry alliance teammates. The team of government LPD 17 and industry-alliance personnel is located in the same building, working literally side by side. For example, the head of the ship design team for the government shares an office with Avondale's shipbuilding head of design.

Collocation has resulted in great savings. Issues are addressed on a real-time basis rather than through the mail system (drafting the issue, staffing it in some other location, and then drafting and mailing a response back).

c. Government/Contractor Teams

This excerpt from the LPD 17 homepage illustrates both the oversight function being replaced with active government participation in the program and the importance LPD 17 places on including all stakeholders right from the beginning of an acquisition or development program.

Earlier ship acquisitions have employed systems engineering principles to include the operator, but often these efforts would gear up precisely when the design, integration, and construction phases were entering a period of minimal flexibility—4 to 7 years after

contract award. In contrast, Team 17's process relies on mission teams to define the overall operational context for a new surface combatant. The mission teams include representation all the way across the shipbuilding-customer base: the Office of the Chief of Naval Operations, the Marine Corps, the fleet commanders, other services, and the organizations that regularly study questions of warfighting. More specialized development and support teams, composed of representatives from the systems commands and design agencies, contribute by translating operational context into specific shipbuilding technology. Coordination is facilitated by a "virtual team" approach that uses computer technology to link geographically dispersed work centers for continuous interaction.

Source: <http://lpd17.wr.nswc.navy.mil/>

3. Advanced Deployable System Program

Government/Contractor Role

The following is the Navy's Advanced Deployable System (ADS) Program Manager's vision as stated in his Program Management Plan:

The Contractor is the key to our success. We intend to work cooperatively to develop an affordable shallow water surveillance capability. The Government team will strive to ensure that the Contractor understands the requirements. The Government team will provide added value to the Contractor's efforts.

D. JOINT PROGRAMS

1. Joint Strike Fighter

a. IPT Organization

Another example of the integrated product and process structure is the Joint Strike Fighter (JSF) program. The Systems Engineering Directorate is organized around IPTs that range from Airframe and Flight Systems (product) to Advanced Cost Estimating and Systems Test (processes).

b. Collocation

The JSF program charter dictated a joint solution to meet the needs of both the Air Force and the Navy. Recognizing the importance of developing a consensus among the Services, senior leadership staffed the program office with equal representation from both Services. In an effort to better understand the requirements and ensure optimum use of program resources, program leadership also demanded collocation of both warfighter and technologist in the program office. As a result, in less than 2 years the program has effectively identified the critical tasks and leveraging technologies necessary to pursue a preferred weapon systems concept that meets both Services' needs.

c. Communication

The JSF program (which has some geographically dispersed elements) uses paperless processes. It emphasizes electronic processes as the standard means of communication and exploits the Internet for efficient, real-time dissemination of program information, including information related to program procurement solicitations.

d. Business Tools

Various computer tools are being developed to take the place of traditional manual methods. The JSF program has developed two software tools to aid in a paperless contracting process: the Bids Evaluation Support Tool (BEST) and the Contracting Officer Support Tool (COST).

BEST is a custom-designed software application that is used to support all aspects of the source selection process. It has the following features:

- Input and display of proposal data
- Evaluation worksheets
- Decision support tools
- Record and display evaluation status
- Question and answer support tools
- Generation and display of reports

COST is a custom-designed software application used to support electronic contracting. It has the following features:

- Procurement initiation document (a procurement request used by NAVAIR) generation and display

- Security Form DD 254
- Contract Data Requirements List (CDRL)
- Statement of Work (SOW)
- Financial Accounting Data Sheet
- Ozone Depleting Substance Form
- Short Form Research Contract

BEST and COST were used by the program to perform electronic source selections and generate electronic contracts. They both are populated with a minimal amount of notional data that will enable a user to browse through the databases and see representative data and results. More information on these tools can be found at <http://www.jast.mil/html/contracts.htm>.

e. Quality Function Deployment

The Joint Strike Fighter program office has found Quality Function Deployment (QFD) to be a very effective tool in the implementation of IPPD. QFD has helped enable the program office to build a consensus across a large group of individuals and organizations representing different experiences, operational needs, and priorities.

f. Modeling and Simulation Environment

The JSF program has adopted a modeling and simulation (M&S) environment that has shortened the timeline for task identification and requirements generation. The program office has pursued an open product and process team approach that includes industry and has developed the modeling tools necessary to replicate the threat environment, operations concept, and JSF weapon system performance. This open product and process approach has enabled the government and industry team to gain early operational insight and make the pertinent trades up front to ensure that performance and affordability objectives are met. Customers and DoD officials alike are convinced that JSF M&S efforts will result in a better product for the warfighter.

g. Simulation Assessment Validation Environments

The JSF program has contracted the development of a virtual manufacturing (VM) program called Simulation Assessment Validation Environments (SAVE) to support low-risk transition of weapon system technology from concept to Engineering and Manufacturing Development (EMD). The objective of the Lockheed SAVE program is

to integrate, implement, and validate low-risk VM technology. The SAVE system can be adapted to any engineering/manufacturing effort and is designed to be employed during all phases of a product's life cycle, from concept design through production. However, the focus of this project is on virtual manufacturing for aircraft structural assemblies as part of the total weapon system development. This program, when developed, will provide significant cost savings to the JSF program.

The primary users of the SAVE system are the Integrated Product Team (IPT) members. SAVE is a comprehensive VM modeling and simulation environment using multiple engineering and manufacturing variables. SAVE's iterative modeling capabilities facilitate the development of the optimum production fabrication/assembly plan. Through electronic links, the integrated simulation technology and its associated database permit worldwide electronic processing of the same VM environment using a common database.

SAVE's full suite of VM software tools, operating in a single environment, allows cost, schedule, and risk assessment to be continually evaluated as the program advances. The integrated tool suite permits verification and refinement of the design and manufacturing process prior to the production of the physical hardware. The SAVE system—

- Integrates the software tools used today in a standalone environment
- Collects and controls the data developed by the IPT in a single logical database
- Provides ready access for all members of the IPT organization to a single database
- Allows transparent communication between IPT members through telecommunications networking, online messaging, and workflow management
- Permits the IPT to conduct EMD simulations to optimize design, producibility, and manufacturing processes while simultaneously reducing cost, schedule, and risk

The SAVE tool suite supports the IPT in a cooperating evaluation of component design, tool design, tolerance analysis, assembly planning, ergonomics, factory floor simulation, schedule simulation, risk assessment, and cost analysis through the SAVE database.

h. Cost as an Independent Variable

Cost as an Independent Variable (CAIV) was implemented on the JSF program by constructing in-depth requirements, cost, and performance trade models (down to subsystems and major components) to set requirements and cost goals/targets at the same time. Only a few key performance parameters (KPPs) were defined and the "users" were involved in the tradeoff studies. An aggressive unit cost target was defined as "less than the cost of a current low-cost fighter." These unit cost targets were included in the Operational Requirements Document (ORD) and early RFPs. Production cost estimates will evolve based on commonality demos and manufacturing process demos to validate process maturity. The program funding was "front-loaded" to provide funding for the demos, other cost reduction tradeoffs, and technology efforts.

Source: <http://www.jast.mil>

2. Joint Air-to-Surface Standoff Missile

Concept development phase studies, USAF/Navy customer input, and acquisition inputs formed the basis for early cost targets in the Joint Air-to-Surface Standoff Missile program. A "Contractor Day" was held to request and obtain industry input. All of this was used to set both development cost and unit cost targets. The unit cost target, in the ORD and RFP, contained both objective and threshold unit cost values that were less than 50 percent of historical predictions. In addition, a "bumper-to-bumper" warranty is included in the unit cost target to cover life cycle cost (LCC). A procurement cost commitment curve is being used for early units, with incentives for costs lower than the curve. The government will have on-line access to the contractor system for cost tracking.

E. GENERAL MODELING AND SIMULATION EXAMPLES

Modeling and simulation are important tools for IPPD. The innovative use of M&S to produce systems better, faster, and cheaper is demonstrated by the following examples:

- The AIM-7P Sea Sparrow was developed and tested using only 10 of the planned 50 launches. The Navy was able to eliminate the remaining 40 flight tests using an end-game effectiveness model to predict the lethality of the missile.

- The GBU-28 was developed in less than 6 weeks during Desert Storm by relying almost exclusively on lethality and vulnerability modeling to design and predict the performance of the system.
- Army testing of bridge durability—a process that traditionally requires 12 weeks to do 3,000 crossings—was reduced to 9 weeks with a mix of actual crossings and simulation.
- At the Air Force's Arnold Engineering Development Center, M&S has been used to lower the cost of testing to the customer. The average time in the PWT-16T wind tunnel has decreased from 6 weeks to 3 to 4 days.
- At Eglin AFB, the use of the Preflight Integration of Munitions and Electronics Systems (PRIMES) ground simulation led to a 35 percent reduction in cost and a 300 percent increase in data capture during a recent flight test program of the APG-63 radar.
- The Naval Air Warfare Center Aircraft Division at Patuxent River used state-of-the-art simulation and ground test capabilities to reduce flight test hours and costs by a third to evaluate ALQ-99 receivers and ALQ-149 communications countermeasures equipment on board the EA-6B aircraft.

1. Predator

M&S has been employed extensively in the Predator Advanced Concept Technology Demonstration (ACTD). It has been used in the broadest context to address global issues such as force mix assessments; in a lesser context, to simulate capabilities in exercises; and, in an even more narrow context, to address specific performance issues, such as the identification of design tradeoff parameters.

a. Force Mix Assessments

At the highest levels, M&S is being used to develop assessments of alternative force mixes of manned and unmanned reconnaissance systems, including Predator. Several classified studies, such as the Intelligence, Surveillance, and Reconnaissance (ISR) Joint Warfighting Capability Assessment (JWCA) and the Command, Control, Communications, and Computers ISR Mission Assessment, are using M&S to identify reconnaissance architecture options for consideration. Additionally, the Defense Airborne Reconnaissance Office architecture development includes, within its force mix, considerations of all unmanned air vehicles (UAVs) including Predator. Predator has been integrated into each of the exercises, and its performance characteristics (platform and sensors) are incorporated in the full range of studies, which include campaign- and

mission-level analyses. The results of these efforts are helping to determine, for example, the number of Predator UAV systems that will be needed to support the objective of "dominant battlespace awareness" at an affordable cost.

b. Capabilities Simulation in Exercises

At the next level, M&S is being used to support Predator participation in operational exercises. In these exercises, virtual Predators are flown by operational users because the limited quantities of real hardware assets are unavailable, and because M&S yields substantive insights at considerably lower cost than operating the real assets. These exercises have contributed significantly to the development of the concepts of operation (CONOPS) for Predator and to an increase in the user knowledge base about the employment of UAVs in general. For instance, in FY96 Predator was modeled in a simulation called the Multiple Unmanned Aerial Vehicle Simulation Environment (MUSE). The MUSE was combined with an improved Joint Surveillance and Target Attack Radar System (JSTARS) simulation to provide a representation of real-time capabilities at selected theater, corps, and division-level command and control headquarters.

c. Performance Issues

At a third level, M&S has been used in the Predator program to assess operational performance, analyze performance parameters, conduct tradeoffs, and evaluate potential system changes and improvements, as in the following examples.

- After the initial radar cross section (RCS) measurements were conducted, computer modeling was used to determine the Predator RCS.
- In accomplishing the initial operational assessment of Predator, limited data from the 1995 European deployment was used as the basis for several engineering models and numerous simulations to complete the analysis of Predator's effectiveness. On many occasions, sufficient field data simply could not be collected to validate critical assessment objectives and M&S was the only practical alternative for evaluation.
- Much of the engineering design of the Predator de-icing system was done through M&S. The determination of ethylene glycol flow requirements, hole emplacement on the front leading edge of the wings, and the flow rates necessary to operate successfully were modeled and then tested in a wind tunnel prior to actual vehicle flight tests.

A recently completed M&S study for the DoD's Director of Operational Test and Evaluation has been used to predict the Predator's coverage capabilities of the target area. This work was done to gain insight into Predator's ability to meet its KPP of a continuous 24-hour target area presence. Because a demonstration of this capability had never been attempted, an event-driven simulation was developed to help identify the factors that might affect Predator's ability to meet this requirement. The model included missions of various ranges, system failures, projected system reliability, and maintenance actions (scheduled and nonscheduled). The study's key finding was that the Predator's ability to continuously monitor a target area (i.e., the target-area presence or time-on-station) is most sensitive to the transit time to the target area and less sensitive to system reliability and maintenance capabilities.

The judicious use of creative modeling and simulation has directly contributed to managing costs on the Predator program by predicting operational effectiveness in conjunction with abbreviated operational assessments, assessing air vehicle survivability cost-effectively, determining optimum system configuration, and assessing alternative force structure options.

Source: <http://www.acq.osd.mil/daro/homepage/predms.htm>

2. Electric Boat Electronic Visualization System

The Electronic Visualization System (EVS) is a computer environment for the design and evaluation of submarines. This system's capabilities include the following:

- Simulation of the performance of the submarine
- Simulation of operations in the control and engine rooms
- Practice manufacturing and interface resolution

The EVS is displayed in a room where the IPPD team can view, display, and communicate with one another to resolve problems. Each person can wear virtual reality devices to be immersed in a virtual environment. Using the EVS, IPT members can perform detailed assembly animations, kinematic studies, analysis animations, and anthropomorphic studies.

The EVS can be accessed at various locations via a secure network; thus, it is available to IPT members at different locations.

3. McDonnell Douglas VM FastTrack

A primary objective of VM tools is to reduce the cost of the first product by iterating design options and manufacturing approaches in the virtual factory environment where the design and manufacturing approach can be solidified at minimal expense. In other words, learning is done on the computer rather than on the factory floor.

McDonnell Douglas demonstrated this in a program called VM FastTrack in which an F-15E production design change was accomplished by simultaneously using both the current paper design approach and commercially available VM techniques. The following benefits were attributed to the VM approach:

- A 33 percent reduction in design release time
- A 27 percent reduction in design cost
- A 19 percent reduction in manufacturing cycle time
- A 20 percent reduction in factory floor space utilization

4. Synthetic Theater of War

Various battlefield simulators located around the country enable the system developers to assess how their concept will perform in different scenarios. Synthetic Theater of War (STOW) is an ACTD jointly sponsored by DARPA and the United States Atlantic Command (USACOM). The STOW program seeks to create a seamless simulated environment that will be usable across the spectrum of service and joint training, crisis rehearsal, doctrine development, battle planning, resource readiness assessment, material development, and system acquisition.

STOW 97 will demonstrate enhanced simulation fidelity based on combat resolution at the weapons system level of detail, realistic simulation of command and control behavior, networking and information flow technology, and the capability to provide knowledge-based autonomous forces in simulation with human-in-the-loop participation wherever desired. STOW 97 will be fully distributed so that forces may participate in exercises or rehearsals from command posts and simulators at widely separated bases or on a live range if desired. Significant additional goals of STOW 97 are to integrate simulation with operational C4I and management information systems and to improve the technology and processes of After Action Reconstruction and Analysis.

Source: <http://www.acq.osd.mil/at/STOW/stow.html>

F. CAIV EXAMPLE: SPACE BASED INFRARED SYSTEM

A customer-led IPT identified the major cost drivers—considering and evaluating customer utility. The cost target was in the ORD and Concept Validation RFP. The customer and Industry were involved in requirements, cost, and performance trade studies to develop a set of affordable and achievable key requirements and, thus, to set the KPPs. For EMD, aggressive cost targets were part of source selection. Contractor trades (with government access) will be conducted to minimize LCC. An innovative incentive fee splits cost savings per unit between the contractor and the government. Approval cycles have been reduced and the EMD RFP streamlined from the expected 1000+ pages to 60 pages. Contractors will participate in IPTs for management, cost, and contracts.

IV. COMMERCIAL INDUSTRY CASE EXAMPLES

In benchmarking for successful IPPD implementation, one should look for the best company practices, whether within the same industry sector or not. As a source of best cases with which to compare DoD program implementation of IPPD, commercial companies have much to offer.

A. CHRYSLER CORPORATION

1. LH Platform

In the late 1980s, the Chrysler Corporation concluded that its functionally based structure would not be sufficient to design the replacements for its present models in a manner that would successfully challenge the competition. Chrysler approached this dilemma by introducing the concepts of platform teams and supplier management to its design and development process.

The first platform team centered on the LH platform, which became Chrysler's new front wheel drive mid- and full-size vehicle. This team combined members from all of the functional areas necessary to design, develop, and test the product and process. Team members were colocated, but the size and composition of the team fluctuated based on the varying functional needs of the project. The team was broken into subgroups that focused on the major subsystems of the vehicle while maintaining an awareness of the vehicle as a whole.

Communication was an essential element in fostering knowledge of the entire project. Such communication efforts included weekly informational meetings among subgroup leaders, daily subgroup meetings, weekly technology reviews, and status review briefings for management every 4 to 6 weeks. In addition to teaming, LH platform team engineers identified suppliers early on and helped to develop a new type of relationship with suppliers—one that allowed Chrysler to set target pricing for the whole vehicle and hand over greater responsibility to the suppliers for subsystems, given specific requirements.

By adopting the platform team and supplier management approaches, Chrysler improved its processes significantly:

- The car design to production cycle was cut from 4.5 to 3.5 years.
- The car design to production cycle was under budget, even given new, more aggressive cost and performance objectives.
- Early involvement of manufacturing allowed problems to be addressed 30 to 50 weeks prior to production, with 100 percent pre-production resolution.
- Prototypes were built using mass production methods, with the first prototype coming at 24 months, compared with 16 months, before production.
- Early consultation among engineers and styling team members resulted in 80 percent engineering feasibility at the clay model stage.
- Seventy percent of the car is produced by outside suppliers.
- Because of success with the LH platform, Chrysler now encompasses four basic platform teams: 1) large car; 2) small car; 3) minivan; and 4) Jeep truck

2. Automobile Hood-Stamping Project

The transition of a stylist's design to a product's engineering and manufacturing form has a major impact on the time necessary to move a prototype from styling to the approval of the auto sheet metal. In order to address this issue within the larger context of decreasing lead times, Chrysler has implemented some new rendering software so that a CAD data model may be more directly translated from the design completed by the body stylist. With these mathematical surface dimensions having been established in the CAD data model, the machine tools are given more precise cutter paths with which to construct clay models and soft metal stamping dies. Previously, the efforts to set the appropriate cutter paths would take from four to five iterations. The level of quality provided through this clay model stage generally resulted in styling sign-off, without the traditional hardwood model stage. Furthermore, as an overall result, the stylist sign-off to prototype time was cut from 30 weeks to 109 hours.

B. FORD MOTOR COMPANY

1. Team Taurus

The Ford Motor Company used teams composed of designers, engineers, production specialists and even some customers in the design and development of its

Ford Taurus and Mercury Sable car line. The team structure focused on assessing the profitability and competitiveness in design and production. The members worked together simultaneously to conceptualize the cars' component parts and determine how these parts should be made. Because of Ford's teaming and implementation of simultaneous engineering on "Team Taurus," it was able to determine the process for the car's assembly before the first clay model stage.

2. Alpha Simultaneous Engineering

Ford Alpha Simultaneous Engineering, an organization that disbanded as part of the Ford 2000 reorganization, was a multifunctional organization that developed innovative product and process improvements by providing technological development services on a project basis throughout Ford. Its members were drawn from the various functional areas, generally for no more than 2- to 5-year appointments so that knowledge could be transferred back to the functional divisions and the concepts of simultaneous engineering spread across the entire organization.

The Alpha Process consisted of four elements.

1. The organization identified customer needs and matched them with processes and technologies that had been developed either inside or outside of Ford.
2. Projects were proposed based on needs and existing process and technology comparisons, and the proposals were then prioritized based on the acceptance and support of customers.
3. A pilot plan was developed and a new process or technology implemented.
4. The pilot plan was evaluated for its costs and benefits.

Ford's Alpha Process was a hands-on demonstration of concurrent engineering practices, methods, and tools. It provided a mechanism for training vast cross-sections of the Ford Motor Company—whether the employees rotated on or merely came in contact with an Alpha project.

a. Automatic Transmission Thermal Management Project

The Automatic Transmission Thermal Management Project, an Alpha project, was tasked to analyze the automatic transmission for thermal management and to devise alternatives that would improve reliability, reduce weight, and lower cost by using an in-tank cooler along with auxiliary air/oil coolers. The project combined stakeholders in teams and committed the different functional groups to work toward the shared objectives

through a Shared Objectives and Interlocking Actions (SOIA). To plan and evaluate alternatives, the team used benchmarking, QFD, and simulation models. To analyze cost/benefit tradeoffs, the team looked at warranties and customer satisfaction impacts given lower transmission temperatures and changing climate and load conditions. Nevertheless, to analyze the transmission subsystem, the team had to consider the whole system. In all, 39 alternatives were considered and simulated using simulation models. By applying the Alpha Process, this project was able to identify additional cooling requirements, which were developed for several vehicles, resulting in savings.

b. Central Lighting System Migration Planning

The Alpha Process was applied in an effort to reduce the cost and increase the reliability of lighting systems. A project was created to use fiber optics in the design of a system containing one central light source for all lights. In its first pilot, the system was developed for the headlights of a 1994 model. Over the next several years, the lighting system alternatives will be used on a pilot and non-pilot basis. By 1999, the system is expected to be in full production and available for use in three Ford models.

3. Romeo Engine

In 1986, the Ford Motor Company implemented concurrent engineering in order to meet some aggressively set goals for the design and development of a new V8 engine. This effort included a concurrent focus on product and process design, a modular design approach, and the use of teaming. Cross-functional teams were assigned to the major subsystem, and product and process engineers were collocated. With the engine design process just under way, Ford selected the site location (Romeo, MI) and began the design of the new engine production plant. The plant was envisioned as “wall-to-wall” shop floor teams, and even machine operators, assemblers, and maintenance employees were involved in the selection and building of the equipment on their lines and the processes to be used in assembling engines. Ford also made arrangements with several suppliers so that they could join in the team activities prior to the prototype stage.

The first complete engine was produced in January 1990. At the time of its launch, the engine had 80 percent fewer defects than previous Ford engine projects. Furthermore, at the time, the engine produced was judged to be the third best engine in its class behind the Lexus and Acura Integra.

4. Vehicle Crash Simulation

The Ford Motor Company has used simulations to decrease the number of physical crash tests necessary to meet established government safety regulations. So far, simulations have been used to investigate the effects on vehicle designs, given occupant restraint, roof-crush, front- and rear-impact, offset car-to-car, and some side impacts. Simulations have also been used during design phases, even before the construction of parametric prototypes. Some results witnessed in using simulation to test vehicle crashes are as follows:

- Reduced the amount of physical testing for front barrier crash by half
- Significant savings seen in the decrease of time necessary to obtain results for early design efforts and better opportunity to increase the number of design alternatives
- Identified the time ratio of prototype-build to computer-build to be 15:1
- Changes made in the simulations take 15 –20 times less time than equivalent changes to sheet metal.

5. Virtual Reality/Synthetic Environments

Ford has explored and implemented methods of applying virtual reality to view and evaluate how the interiors and exteriors of a vehicle are visualized. There are also hopes of applying these virtual reality models to the manufacturing process. The models would be used to assess the sequence of assembly. This use should result in fewer engineering changes during the later phases of design and development.

6. Rapid Prototyping/Free Form Fabrication

Rapid Prototyping or Free Form Fabrication represents the integration of a solid model CAD system with “desktop manufacturing” systems in order to rapidly prototype component designs. Parts and components can be generated directly on the “desktop” from the available CAD data. This has reduced the time and money spent by traditional modelers in the construction of prototypes. Ford specifically implemented rapid prototyping in the design and development of a new automobile engine crankshaft. During the crankshaft’s design, changes were made with respect to the constraint parameters in the engine’s data model, in order to create and determine the dimensional accuracy of the crankshaft prototype. This resulted in a crankshaft being produced, placed in the motor, and tested within 2 days of the generation of its computer design.

7. Parametric Linkage of Product Design Models

Because many auto industry subsystem and component designs are adaptations of previous designs, Ford has invested in the creation and maintenance system that consists of product design models and their connections. This process uses parametric designs from CAD systems to link to components via data models. With the proper linkages in place, a change made to one component will automatically prompt the appropriate changes to also be made to other linked components and generate the necessary design and specifications for tools and fixtures.

C. EATON CORPORATION—ROMEO ENGINE

The Engine Components Division of the Eaton Corporation is a long-time supplier of parts to the Ford Motor Company's Engine Division, but in 1986 Ford proposed that Eaton play a more active role in the development of Ford's planned V8 engine. This involved a shift from a traditional prime-supplier relationship to one in which Eaton would assume the role of a full-service supplier. Under this new approach, a supplier participates from an early stage in the process and is given a degree of responsibility for a subsystem from design through any necessary post-production, follow-up services. Eaton, therefore, gained responsibility for the design and development of the valve train assembly for Ford's V-8 engine. Moreover, Ford gave Eaton the responsibility to price the components of the subsystem it was designing, stipulating only a target price to be met for the total subsystem.

Eaton became involved early in this new V-8 engine's development phase. It participated in monthly and informational meetings, and a full-time program manager was committed to coordinating the engineering efforts of both Eaton and Ford. By acquiring in-depth knowledge of Eaton's product and processes early and investing in DFM/DFA training, Ford was able to identify design innovations that increased the life of the product and resulted in savings per part. Indeed, one such innovation included replacing the traditional cast and machinery with the stamping of the rocker arms, which would result in \$7 million in savings to Ford annually.

Eaton stayed involved through the manufacturing process development phase, helping to ensure that the Eaton manufacturing process met Ford requirements. During this phase, Ford also required that Eaton flowdown its quality system as a means to ensure that its suppliers would produce good parts and ship them on time. Eaton teamed individuals from different functional areas throughout the design and manufacturing

process phases, but it did not collocate the team members. The members joined and left the team based on the needs of the project.

The success of Eaton's role in Ford's V-8 engine project is evidenced by the following:

- Eaton reached a Process Performance Index (C_{pk}) of 2.0 for its identified critical characteristics (1part/billion defective).
- The valve train was designed at lower cost.
- All excess cost had been removed during design, exceeding Ford's goal of 5 percent annual cost reductions on its products.
- Eaton's reputation for quality and innovation was enhanced, resulting in increased demand for Eaton as a full-service supplier.
- Quality processes discovered through Ford's V-8 engine could be applied to additional Eaton programs.

D. GENERAL MOTORS

1. H-Cars

During the 1980s, General Motors (GM) devoted \$80 billion to its manufacturing enhancements, but few quality enhancements resulted, production cost remained high, and GM ended up taking losses and experiencing downsizing. Thus, when GM embarked upon the redesign of its H-car series (1992 Buick LeSabre, Pontiac Bonneville, and Oldsmobile 88), the company applied a new approach—simultaneous design—to the development of these models' product and manufacturing processes. GM also implemented its design for manufacturing philosophy, which calls for decreasing the number of components and improving assembly ease and time in order to increase quality and lower cost. GM management said: "With the H-cars, GM is getting another chance to actually walk the talk of the 1980s and apply manufacturing and assembly forethought to product design and development while winning back customers with high quality and lower manufacturing costs."

2. Buick LeSabre

GM's effort to design the 1992 Buick LeSabre involved teaming, a customer-driven systems engineering approach, and benchmarking. The LeSabre was designed simultaneously by 50 teams, which were assigned to its six subsystems. Each team

consisted of individuals representing different function areas and suppliers. The systems engineering approach was given a customer focus that forced teams to look at subsystem tradeoffs in the context of the whole vehicle, specifically with respect to customer needs such as wind noise, aerodynamics, and total vehicle costs. Furthermore, GM implemented benchmarking. First, GM's design engineering solutions were benchmarked against those of Japanese and European companies. Then, 400 of the LeSabre's features were benchmarked against the Ford Crown Victoria, Mercury Marquis, Chrysler New Yorker, and Nissan Maxima.

With this new approach, GM was able to cut the 1992 Buick LeSabre's product development time from 49 to 34 months. Moreover, LeSabre had 40 percent fewer parts and could be assembled in one-fifth of the time previously required. As a specific subsystem assembly example, LeSabre's front grille originally was to comprise 52 parts and take 9 minutes to assemble, but under the new approach it had only 16 parts that could be assembled in 3.5 minutes by the time the 1993 model was released. Additional results were as follows:

- 45 percent better ride quality (ride motion, softness, smoothness, and evenness of motion)
- 14 percent better handling
- Better structural frequency (sensitivity to shaking)
- 20 percent better in the effort needed to close the door
- 33 percent better in the effort to close the trunk

3. Saturn

General Motors undertook the reconfiguration of its building layout and organization of Saturn engineering in order to better facilitate its synchronous, just-in-time engineering approach. Those previously spread out over three different buildings are now collocated in one. The configuration of the collocation is based on a particular car section. Within these sections, the team leader, who maintains responsibility to ensure quality the first time, serves as a central focus point with the engineers and designers in the surrounding area. The engineering teams produce designs, specifications, drawings, and sometimes even 3-D mockups that are audited and subjected to peer review. Smaller teams are created as needed for the design and development of smaller subsystems, as was witnessed in the development of the airbag as an option by May 1992.

E. TOYOTA

1. General

Toyota is often thought of as a pioneer of concurrent engineering. In practice, however, Toyota's implementation of this concept diverges from the traditional norm. Toyota uses a variation called *set-based concurrent engineering*, in which designers conceptualize and create parameters for a set of design alternatives. Numerous design alternatives exist from conceptualization through the one-fifth clay model stage. During this time, the alternatives are analyzed and evaluated to determine which is most superior. This approach differs greatly from traditional concurrent engineering, in which a single alternative is revised and modified through an iterative process. While the set-based approach provides a broad array of design alternatives for a single product objective, Toyota's design possibilities are constrained throughout by the use of engineering checklists to record and document infeasible designs by function group.

As with traditional concurrent engineering, Toyota's adaptation uses teaming to perform the product and process development work. At a project's peak, as many as 500 people may be participating in the project's various subteams. The teams are multifunctional in nature, but their members are not solely dedicated to the project or collocated. The heads of the functional groups and the project group select individuals based on the particular needs of the project at the time. Subteams are given the authority and responsibility to determine the details of the subsystem's development plan, but they must bear in mind the overall project goals and satisfy the customer.

Using the methods described, Toyota is able to complete its product concept-to-production cycle in 27 months.

2. Product Development Process

Toyota is widely considered a leader in designing vehicles quickly with less engineering time. Despite this success, Toyota implements a number of processes and practices that would seem to go against the prevailing best practice wisdom of product design and development. For example:

- It is a matrix organization consisting of strong functional groups
- Engineers are only loaned to development teams on an as-needed basis
- Design and manufacturing engineers remain separate entities

- The voice of the customer is interpreted through the chief engineer rather than QFD, Taguchi experiments, etc.
- Communication takes place primarily in written forms
- A timeline for the development process is set individually for each project
- Many alternatives are pursued and evaluated in a quick and efficient manner

Toyota's Technical Center consists of four Vehicle Development Centers (VDC):

- VDC1 – rear wheel drive passenger cars
- VDC2 – front wheel drive passenger cars
- VDC3 – commercial and recreational vehicles
- VDC4 – components and systems development

Each of the VDCs is organized as a matrix of functional groups. A chief engineer heads each VDC and serves as the lead in development projects. The chief engineer has a broad knowledge of Toyota and vehicle design, acts as the voice of the customers, sets the vehicle concept and sells it to management, and coordinates the efforts of the VDCs functional group members in their work on product design and development projects.

At Toyota, all programs center on the same set of milestones and major events for the product design and development process, although they may be somewhat tailored by the chief engineer to meet specific needs. In general, the following five phases emerge:

- Concept phase
- System design phase
- Detail design phase
- Test and verification phase
- Trial production phase

Suppliers are incorporated early in the design process. In fact, during the concept phase, suppliers are asked to present new technological advances and how they could be used to improve the current part in question. Toyota establishes goals and design requirements but allows the supplier freedom with respect to design details.

F. HEWLETT-PACKARD

Hewlett-Packard is constrained by the short lives of its products—some only 18 months long. The company is therefore aggressive in its efforts to develop products

ahead of the competition. During the 1980s, Hewlett-Packard followed a Total Quality Control (TQC) methodology based on the following principles: 1) every activity is a process that can be documented and measured; 2) the customer's viewpoint should determine the quality of a process; 3) each process has the potential for improvement; and 4) total participation is required to achieve principles 1 through 3.

Still by 1985, Hewlett-Packard was being forced to respond to increased competition in the spectrum analyzers and electronic measuring devices industry. The company decided to change its way of doing business by implementing new management practices, innovative design and production concepts and technologies, and a new marketing approach. Concurrent engineering proved to be a central concept to Hewlett-Packard's new approach. Teams were created using employees from all functional groups and suppliers. The new marketing approach made it possible to look at competitors as improvement opportunities.

Under the new approach, Hewlett-Packard was able to develop a product in half the time that it usually took, and the product managed to capture 75 percent of the Japanese market. After a tough 1990, Hewlett-Packard further adjusted its organizational structure so that decisions would be made at lower levels. As a result, revenues increased 11 percent, and net earnings in the first half of FY91 increased 22 percent.

G. ALLIEDSIGNAL

AlliedSignal has two approaches to its objective of total product quality and commitment to excellence. First, through its technology excellence endeavors, AlliedSignal has focused on management and processes in an effort to improve product quality. The company has introduced product scorecards as a means of tracking the present and goal sigmas for parts. In particular, variations are identified for deficient design margins, substandard incoming parts and material, and inadequate process capabilities. By introducing such methods, AlliedSignal is expected to increase quality, reduce cycle times, and better satisfy its customers. Second, and more directly related to the certification of suppliers, AlliedSignal has implemented an Integrated Product Development System (IPDS) that addresses such issues as life cycle acquisition, collaboration across traditional functional areas, and the sharing of accountability. IPDS teams use ISO 9001 as a reference checklist to determine supplier compliance.

H. WHIRLPOOL CORPORATION

The household appliance market in which the Whirlpool Corporation operates is known for its tough competition and declining product prices. As at least a partial means of addressing the conditions of this market, Whirlpool has undertaken the restructuring of its design process in order to design products that customers want in less time and with improved quality and manufacturing costs. To that end, Whirlpool adjusted its organizational structure to include the use of cross-functional teams, the integration of suppliers into the product development process, the introduction of systems to handle the workflow and its related information, and the use of concurrent engineering tools and methods. The use of these approaches is credited with reducing the product concept-to-production time and cost by 25 percent.

Whirlpool has a unique overall organizational structure that combines aspects of functional, product, and brand management organizations. There are four groups that relate directly to the product development organization: dryer engineering, washer engineering, dishwasher engineering, and product services. In general, engineers are divided among electrical and mechanical engineering disciplines and the Kenmore, Whirlpool, and Kitchenmaid product brands. However, the concept of cross-functional teams at Whirlpool got its start in 1989 when a group of design and manufacturing engineers attended training on DFM. Upon the conclusion of this training, six cross-functional teams (and various subteams) were created to identify opportunities to apply DFM to Whirlpool products. The success of these initial efforts has resulted in the more formal adoption of cross-functional teaming in product design, with collaborative efforts including marketing, design engineering, manufacturing, procurement, advanced development, finance, advanced research, customers, and critical suppliers. Team size and composition fluctuate depending upon the needs of the project, but the majority of team members are collocated.

One of the more dramatic changes achieved by the use of the teaming structure has been the integration of suppliers into the design and development process. Whirlpool has implemented a system in which procurement reviews suppliers' cost, quality, and timeliness records and identifies those suppliers capable of participating in the early stages of product design. Since these suppliers having been pre-identified, team members can then turn to this list to select suppliers for inclusion in their product design and development teams. In addition to playing an active role in the design and development process, suppliers have also been given increased latitude in product testing based on

Whirlpool specifications for reliability testing and application testing to determine how their parts will fit and/or function within the whole product.

Whirlpool uses three systems to manage the workflow. The Product-to-Product Planning Department looks at future projects and acts as an integrator of activities across product brands by establishing project priorities, timetables, and budgets. The Customer to Customer (C2C) program management system is linked to the cross-functional team approach and manages the workflow across the life-cycle phases of product development. C2C brings a business planning focus to cross-functional teams and provides the structure necessary for the team to satisfy the criteria for moving through the phases of the development process. The computer-based project management system provides a means for all team members to have access to track their detailed tasks and schedules while also keeping in mind the overall timelines.

Whirlpool also uses a long list of concurrent engineering methods and tools. Some of these include CAD and IGE, Finite Element Analysis (FEA), DFM, QFD, and Activity Based Costing (ABC). Various tools are tried in different product efforts and, once they are proven useful, they are then more formally incorporated into the design and development process.

1. Next Generation Washer

In response to 1999 standards established by the Department of Energy, Whirlpool embarked upon a project to redesign a washer. The project's design and development process has been structured around various cross-functional teams, including the participation of key suppliers. Prototypes have also been used to evaluate concepts and implement necessary corrections so that all are addressed by prototype round three.

a. Plastic Tub

A subsystem team, including members from suppliers, was tasked with the design and development of the Next Generation Washer's plastic tub. Supplier participation provided added product expertise and engineering analysis and simulation. The process was concurrent and iterative in that it was an ongoing effort: the product was designed, the design was reviewed using finite element analysis, and prototypes were built in a simultaneous fashion. The team leader maintained a detailed task schedule for a 3-month

period and used e-mail and project scheduling to foster communication among team members. Some results of this effort were as follows:

- Prototype test results were available sooner
- A tooled part was available for test sooner
- A 3- to 4-month time savings in achieving a good part by the end of the first prototype was estimated
- Collocation was viewed well by the team, but was isolating to others outside the team and management (Team leader estimates that 80 percent of time was spent interfacing with those outside the team.)

b. Wire Harness Design

This project was sparked by a study of the cost alternatives that suppliers could provide concerning the production of wire harnesses. The study concluded that by specially designing its wire harnesses, Whirlpool might have been inadvertently driving up the cost of this subsystem. Whirlpool, therefore, created a database that contained the suppliers' prices for parts and components which could be used with the provided formulas to determine the prices of different combinations of these parts. Design teams can use the database, while in the design phase, to figure out the cost of the alternative that is being worked on. This approach has resulted in—

- Shorter development lead time
- Reduced cost of wire harnesses
- Faster production of product design samples (suppliers are now able to provide product design samples within 2 days, rather than the previous several weeks)

c. Quality of Service Meetings

To determine how to better serve Whirlpool engineering, the product service group implemented a storyboarding approach. The group solicited positive and negative feedback on product service. Problem areas were then prioritized and cross-functional teams were formed to address the issues raised. Because of its success, engineers are now adopting this approach so they can better understand and improve the services they provide to their customers.

2. World Washer Project

The World Washer Project represents Whirlpool's effort to develop a new international washer. The project used collocated, cross-functional teams, a modular design approach, customer and supplier participation, benchmarking, and various other concurrent engineering methods and tools (2-D CAD, DFM, Taguchi methods, QFD, and other simulations and analysis). In approaching this project, the amount of production, facility layout, product modularity, and issues of local market requirements were taken into account early in the design phase. As a result of Whirlpool's implementation of the above tools and methods and consideration of a vast array of issues early in the design process, the project had designed and developed a new washer, as well as its three production plants in Brazil, India, and Mexico, within 3 years.

Whirlpool took great pains to design and produce a product that was sensitive to the local conditions and capabilities of the identified plant site locations.

- It collocated engineers from Brazil, India, and Mexico to Michigan so that they could provide insight into the particular characteristics of their countries and markets and actively participate in the design and development of the product and production facilities.
- Whirlpool decided early on to avoid secondary production processes when they were not compatible with the material capabilities of the production sites. The company realized that this could initially translate into higher material costs, but it projected that any increases would be offset by two factors: 1) the reduced need for capital investment to support the introduction of these secondary processes, and 2) fewer quality problems due to intermediary processes. Given this, Whirlpool decided that a stainless steel basket would be designed and used in Brazil and India, and that Mexico was better suited for producing a porcelain covered steel basket.
- Whirlpool developed generic controller software that could be configured to reflect divergent local characteristics and requirements pertaining to wash cycles, temperature, and levels of water consumption.

The production plant facilities were originally designed to produce 150 percent of the market share. The production lines, however, were designed to be modular and set up in parallel for quick response to changed production requirements.

Whirlpool's efforts on the World Washer Project have produced good results:

- The manufacturing production system is 10 times less complex.

- Production facilities have been specifically designed for simplicity, market size, and the minimization of capital.
- The decrease in overall complexity has reduced the need for design simulation for production facilities in order to determine capacity confidence.

I. BOEING AIRCRAFT

For the first time in the company's history, Boeing Aircraft designed the entire 777 aircraft on a computer and successfully built it without a complete physical mock-up. Using an extensive virtual prototyping (VP) process, Boeing effectively brought together 33 subcontractors spread across 13 countries, all operating in a digital electronic format. The use of VP has resulted in a 93 percent reduction in design changes compared with design changes in Boeing's previous aircraft, and the greatest first-time form and fit ever achieved by the company. Furthermore, VP has improved the accuracy of tool design by a factor of 10. Boeing found that its product and process teams benefited from VP because it stimulated the employees' creativity.

J. XEROX

In the late 1970s Xerox controlled 80 percent of the copier market. By 1982, its portion of the market had dropped to 45 percent and Xerox was faced with the need to decrease its new product development time in order to remain competitive. Xerox undertook its new modified approach to new product design and development with its 10-series copier products. As a result, by 1984, Xerox had succeeded in cutting its development cycle time in half.

K. COMPAQ COMPUTER CORPORATION

The Compaq Computer Corporation has worked to decrease its company and industry average product development cycle time from 12 to 18 months to less than 6 to 9 months. Compaq also worked closely with Intel, the 80386 microprocessor chip supplier, to ensure the compatibility of both companies' processes. The result was the introduction of the DeskPro386 microcomputer in 1.5 months.

L. EASTMAN KODAK COMPANY

The Eastman Kodak Company used concurrent engineering in the design and development of its single use "Funsaver" camera. This project's approach included

cooperation among personnel from product design and production functional areas and the incorporation of CAD tools. The result was a marketable product within 9 months of the product concept stage. Kodak also used concurrent engineering to design and develop its new Ektar film in a quarter of the time usually needed.

M. MAZDA—MIATA

Mazda's approach to the design and development of a new vehicle centers on the inclusion of manufacturing in the product development cycle. The company believes that early involvement and cooperation among product design and manufacturing engineers will result in a more consistent product and minimum investment. Under this approach, product and manufacturing engineers exchange detailed information and requirements throughout the flexible design of the product and manufacturing processes. The engineers focus on the root causes of problems and the development of new engines that require only slight modifications for existing production lines. The net result is lower cost.

In work on the design of the Miata, manufacturing's involvement led to the development and use of lightweight ductile cast iron steering knuckles that reduced the weight of the vehicle by 2.2 pounds. Furthermore, a painting technique was developed to give the vehicles a more polished and durable paint finish.

N. HAMILTON STANDARD ELECTRONIC MANUFACTURING CENTER

The Hamilton Standard Electronic Manufacturing Center uses an approach to concurrent engineering that strives to link product concept, design, and related processes to the necessary support functions. The goals of Hamilton's concurrent engineering efforts are to satisfy the customer, improve quality, cut the cycle time and cost of concept to marketable product, and improve the transition of a new product from engineering to manufacture. This is accomplished using multifunctional teams. In addition, each project passes through the same four phases of Hamilton's design and development process: 1) pre-proposal, 2) proposal preparation, 3) product and process design and development, and 4) product manufacture and deployment.

O. KAISER ELECTRONICS

Kaiser Electronics uses teams to perform the design and development of its new products. These teams are multifunctional and, whenever possible, collocated. Certain

customers and major contractors/suppliers are included in the teaming efforts throughout the product development phase. Training is provided to team members on effective teaming, development processes, techniques, tools, etc. The teams provide data to the functional areas, and design decisions are made by consensus. Kaiser's approach to design and development has resulted in a 20 percent decrease in the system engineering time.

P. JLG INDUSTRIES, INC.

JLG Industries, Inc. is an international manufacturer, distributor, and marketer of aerial work platforms and vertical personnel lifts. It has adopted a new product development process in which the product's entire life cycle is included in the design and development of a product. This new approach has led JLG to focus more on corporate strategic planning and introduce the use of cross-functional teams. As a result:

- The product specifications remain more stable throughout the project.
- A set process is in place that includes phases and exit criteria.
- Products are developed around common platforms in families.

Front-end process costs are higher but are expected to be offset by a decrease in design modifications, lower warranty costs, and fewer dissatisfied customers.

Q. McDONNELL DOUGLAS AEROSPACE

1. MDA-West

McDonnell Douglas Aerospace (MDA)-West, Huntington Beach, CA, has adopted concurrent engineering as a means to stay competitive, improve the quality of its products, reduce the production costs, and reduce cycle times. Management has, furthermore, embraced concurrent engineering as being consistent with its corporate vision of producing each product right the first time.

Concurrent engineering efforts at MDA-West are spearheaded by the use of multifunctional teams. To facilitate this team focus, MDA has moved from a traditionally functional organizational structure to one that is more of a flexible matrix.

In addition to teaming, MDA-West has worked to create a system of computers, workstations, and desktops to be used for sharing design and development ideas and data. This configuration allows for real-time concurrent engineering regardless of team

member's location. CAE/CAD/CAM support tools have been simplified by standardizing Unigraphics design and manufacturing software to run on HP700 series workstations and Macintosh desktop computers on the Space Station Freedom program.

As a result of concurrent engineering MDA has realized a number of benefits: greater efficiency in communication up front; awareness among all team players of downstream needs; a reduction in non-value added activities; networking relationships between team members and suppliers; higher first-time quality in all program phases; more use of shared data; a reduction in the number of parts; an increase in performance on schedule; and a cut in the life cycle cost.

2. MDA-St. Louis, MO

In 1992 McDonnell Douglas Aerospace-St. Louis (MDA-St. Louis) started an IPD program to identify all of the activities and actors necessary to design, produce, and deliver a product. When adjusting to this new design and development approach, MDA-St. Louis benchmarked itself against several other companies, including Texas Instruments, Ford, Northrop, etc. The company introduced multidiscipline Integrated Product Teams (IPTs) and collocated manufacturing personnel with design engineers.

Team members are selected based on their skills and fit with the rest of the team. Each team strives to meet design for manufacturability and ease of assembly goals in the delivery of a specific product or service to the customer. Team members are required to complete 14 hours of training, and the team leader is required to receive more. MDA-St. Louis also uses IPD Quality Measures as an on-line means for managers and team members to monitor team and project performance and progress toward established goals. One aircraft design team has been responsible for a 33 percent decrease in the number of parts and elimination of 11,000 defects per aircraft.

R. TANDEM COMPUTERS, INC.

Tandem Computers designed a specific five-step process to be followed in new product development to ensure that the product is considered throughout its life cycle. The phases that a product passes through from concept to post-production are as follows: Phase 0-Concept; Phase 1-Investigation and Requirements; Phase 2-Specification and Design; Phase 3-Development and Verification; Phase 4-Pre-production and Introduction; and Phase 5-Production and Support. Multifunctional core teams and subteams are used to carry out the work in this design and development process. Each

phase is accompanied by a certain set of deliverables that must be met by the team in order to exit a phase and begin a new one. Although these phase tasks and deliverables are outlined, the teams do retain some flexibility in how these tasks and deliverables are met.

Appendix A

CASE STUDIES FROM ARMY DOCUMENT:

***ARMY EFFORTS TO IMPLEMENT INTEGRATED PRODUCT AND
PROCESS MANAGEMENT (IPPM)***

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CASE STUDIES FROM ARMY DOCUMENT

1. TUBE LAUNCHED OPTICALLY TRACKED WIRE GUIDED (TOW) MISSILE IMPROVED TARGET ACQUISITION SYSTEM (ITAS)

The TOW ITAS is a materiel change, technology insertion to accommodate TOW 2 on the High Mobility Multipurpose Wheeled Vehicle and ground mount systems. ITAS provides improved target detection and acquisition range, improved probability of hit, and enhanced fire control capabilities that will upgrade the anti-armor punch of light forces. The ITAS accommodates all TOW missiles and has provisions to accommodate future new missiles. The ITAS is a Category III acquisition but, for test and evaluation oversight purposes, it is a Category I system. The ITAS project is under the direction of the Program Executive Officer (PEO), Tactical Missiles. The TOW ITAS Product Manager (PM) reports to the Project Manager, Close Combat Anti-armor Weapons Systems (CCAWS).

The TOW ITAS was in Engineering and Manufacturing Development (EMD) when this case study was written. The Army competitively awarded an EMD contract to Texas Instruments (TI), Dallas, TX on 30 April 1993. The Preliminary Design Review (PDR) concluded in November 1993 and the Critical Design Review (CDR) in August 1994. Both reviews were event, not schedule, driven. Satisfactory completion of predetermined milestones along paths to discrete events brought both reviews to a successful closure.

An appointed team of government personnel wrote the TOW ITAS Request for Proposal (RFP). They streamlined the RFP and organized it to address program management, design, configuration management, production, and test. The resulting RFP did not have separate sections for each of the traditional functional areas. The RFP did request that the contractor organize a Concurrent Engineering (CE) team to execute the EMD contract. No limitations were imposed on how the team was to be organized. The TI proposal outlined their CE team organization. An Army Materiel Command Roadshow II reviewed the RFP and provided comments to the CCAWS Project Management Office (PMO) in the fall of 1992.

The CCAWS PMO organized and chartered a Joint Industry-Government Team, called Team TOW ITAS, to define, plan, control, and direct critical processes in EMD and production. All functional disciplines and test and evaluation agencies were included in Team TOW ITAS. The scope of team activities included identification and continuous improvement of processes critical to program success. The Team had to ensure synchronization of program activities; open, rapid communications; real-time problem solving; and application of appropriate skills, resources, and timely management decisions. However, the Team could neither alter independent evaluator's missions in any way nor usurp the Test and Integration Working Group's (TIWG) prerogatives. The team comprised three elements: the Executive Steering Group (ESG), the Management Working Group (MWG), and the Functional Execution Element (FEE).

The ESG provided senior-level oversight and overall policy direction. The PEO, Tactical Missiles, was the chair. Members included representatives from the offices of the Deputy Undersecretary of the Army for Operations Research; Commander, U.S. Army Missile Command (MICOM); Commandant, U.S. Army Infantry School (USAIS); senior level management representatives from the Army Materiel Systems Analysis Activity (AMSAA), Operational Test and Evaluation Command (OPTEC), Test and Evaluation Command (TECOM), and Night Vision and Electronic Sensors Directorate (NVESD); and the contractor vice president. The ESG met annually or more often as required.

The MWG provided programmatic guidance and direction. The Project Manager, CCAWS, was the chair. Members include a director-level contractor representative and, generally, director-level representatives from MICOM, USAIS, AMSAA, TECOM, NVESD, and other organizations that have direct involvement or oversight responsibility for the program. The MWG met semiannually or more often as required.

The FEE managed daily program activity, focusing on performance, schedule, cost, and supportability. The FEE was responsible for early problem identification and course of action recommendations. The FEE addressed the ESG/MWG via the TOW ITAS PM. Its normal forum was the daily workplace and the management interchange meetings. The FEE included both government and contractor representatives from all the functional areas. Also included were representatives from the Defense Plant Representative Office (DPRO), USAIS, AMSAA, TECOM, and other organizations. The

FEE members kept abreast of activity through the MWG and the TOW ITAS PM channels as FEE did not meet as a complete entity after the initial kickoff meeting.

Soldier users were an integral part of the ITAS project. A user representative served on the Source Selection and Evaluation Board (SSEB). An early user demonstration in August 1993 at Fort Benning and Redstone Arsenal included appropriate military occupational specialty representatives. The demonstration allowed soldiers to evaluate prototypes and concepts as a part of the path to the PDR. Ongoing limited user tests provide user evaluation early in the project. A user also participated in the MWG and ESG meetings.

The entire FEE team met together for a one-time kickoff meeting about one month after contract award. The meeting, held at the contractor's facility, lasted one week. The TOW ITAS PM started the meeting by laying the ground rules for the project and instructing the team what to accomplish. The contractor presented a briefing to overview the contract and their top-level plans for executing it. After the contract briefing, the government and contractor FEE members met in groups with their functional counterparts. As instructed, the team members got to know each other and, line by line, perused those parts of the contract relating to their areas of responsibility. They had to understand the contract and agree about what was to be done and by whom.

Clear ground rules were in effect for Team TOW ITAS. The contractor was totally responsible for the design and for meeting the requirements of the contract. The government's role was to advise, make suggestions, and help where possible. The contractor took whatever advice he wished, but he was totally responsible for meeting contract requirements.

TI had a well-established Integrated Product Development Process (IPDP). The company had used the process on several projects and had developed a comprehensive training program. All TI members of the FEE team received the IPDP training. Five government members of the FEE team also participated in TI's IPDP training. These five government members helped to facilitate the operation of the government FEE team. As an adjunct to TI's IPDP, the contractor and government partners jointly developed and monitored a series of tailored paths to prominent scheduled milestones (e.g., PDR, CDR, and Test). These paths defined the successful entry and exit criteria.

Government members of the FEE team met weekly at the CCAWS project office to exchange information and coordinate plans. TI had a resident representative stationed

in Huntsville, AL, who attended these meetings. Government members of the FEE team also participate as needed in a monthly briefing to the PM, CCAWS. While government personnel do not work in a common office at MICOM, reasonable proximity and good communication systems still allowed the team members to work together effectively. Contractor members of the FEE team worked together at the TI facility in Dallas, TX. The contractor team met weekly at TI. At least one government FEE representative attended these meetings. Government personnel from the FEE team traveled to TI to meet with their counterparts as needed. The heaviest concentration of government personnel at TI was between PDR and CDR. Besides face-to-face meetings, telephone, fax and videoconferencing communications were extensive. Government personnel had on-line, real-time access at MICOM to TI's TOW ITAS database for timely review of drawings and other data.

The FEE team made its own decisions whenever possible. This worked well because team members were able to establish ownership of the process during the kick-off meeting. Issues that could not be resolved by the FEE or recommendations that required efforts outside the scope of the contract took an upward route through the MWG to the ITAS PM. If necessary, they went to the CCAWS Project Manager for resolution.

The people who worked on each of the Work Breakdown Structure (WBS) elements tracked the expenditures for those elements. The contractor prepared the cost performance report that showed expenditures for each WBS element. For each element, a government FEE member was appointed to track expenditures. The government member reviewed the report with his contractor counterpart to ensure that budget and schedule were maintained. A joint videoconference cost review convened once per month to track overall program costs.

The approach taken on the TOW ITAS project reduced the need for formal reviews. Formal program reviews with the contractor occurred semiannually rather than monthly. The contractor prepared fewer deliverables because the government had ready access to information as it develops. To reduce costs further, the government requested only one copy of each deliverable.

No problems arose concerning proprietary information. The emphasis was on the use of non-proprietary commercial technology. There was no proprietary process involved in the production of the ITAS.

The concurrent engineering approach taken for the TOW ITAS project was effective in controlling cost and schedule. Timely, direct communications increased the effectiveness of the personnel assigned to the program.

Persons interviewed: LTC Tom Harrison, Product Manager, TOW ITAS,
DSN 645-0318

Mr. Tom Hart, Production Manager, MICOM Systems
Engineering and Production Directorate, Production
Engineering Division, DSN 779-6566

Interviewed by: Mr. Walt Roll, Industrial Engineer, AMXIB-P, DSN 782-5617

2. CLOSE COMBAT TACTICAL TRAINER

The Close Combat Tactical Trainer (CCTT) was an Acquisition Category III program that was in the third year of a 5-year development when this case was written. From the beginning of the Close Combat Tactical Trainer (CCTT) program, a continuing emphasis was placed on applying the principles of Concurrent Engineering (CE) to the development effort. In an early memorandum, COL Shiflett, the PM for Combined Arms Tactical Trainers (PM CATT), observed, "CCTT is a complex system with literally thousands of requirements, many of which are subjective by their very nature." He continued, "CE will allow us to mature the customer's requirements as the design evolves and allow everyone who is affected by the trainer's design, which is just about all of us, to have an input into the design early enough to prevent surprises" Thus, the purpose of CE was twofold: (1) to improve the exchange of information needed to ensure that the contractor understood and could execute in the CCTT training system the complex behaviors being sought by the Army and (2) to reduce the risks involved in development of this important Army training system.

The CCTT is a collective training system in which armor and mechanized infantry units man full-crew simulators of their weapons systems to conduct unit training in a combined arms environment. Simulated elements replicating combat vehicles, weapons systems, and command and control elements are networked using Distributed Interactive Simulations (DIS) protocols for real-time, fully interactive, collective task training on computer-generated terrain.

Based on an open competition, a cost plus award fee contract was awarded in November 1992 to IBM Federal systems, now Loral Federal Systems Company. The Statement of Work (SOW) for the CCTT contract stressed the use of a spiral/incremental

development approach and the use of non-developmental software and hardware in the CCTT design. Heavy emphasis was also placed on reusing and re-engineering existing and developed software. In addition, the SOW required the contractor to use a system design process that concurrently integrated the efforts of all functional areas including producibility engineering and planning, software/firmware, product assurance, test and evaluation, logistics, and configuration management.

For the CCTT development effort, IBM gathered a team composed of ECC International, Evans and Sutherland, SAIC, PULAU, and Dynamics Research Corporation. As a way to overcome the difficulties of coordinating the efforts of this diverse team and in response to the SOW requirement to integrate the efforts of all functional areas concurrently, IBM proposed that personnel assigned to the CCTT program from all team companies be gathered into an Integrated Development Team (IDT) for the duration of the effort. This IDT was located in the CCTT Integrated Development Facility (IDF) that was less than a mile from the PM CATT offices in Orlando, FL. Two of the subcontractors performed major portions of their work at their base facilities. ECC International, also located in Orlando, was responsible for manufacturing the simulator hardware, and Evans & Sutherland, located in Salt Lake City, Utah, supplied the image generators. Both companies, however, maintained lead functional personnel at the IDF who coordinated the work with their base facilities.

The IDT was structured into five coordinated CE teams assigned by major system components or products. Under the guidance of the System Integration CE team, individual CE teams addressed development of the modules, the visual system, and the workstations. Each of the four area teams had members from all functional areas.

The PM CATT, who managed the CCTT through Program Directors, led the Army team. These directors were assisted by a team of about 80 functional members drawn from the Simulation, Training and Instrumentation Command (STRICOM), the Naval Air Warfare Center-Training Systems Division, several other Army agencies and offices, the Defense Contracts Management Administration Office, and Nations, Inc., a support contractor. They represented a full range of functional specialties from system architecture, hardware and software engineering, production engineering, logistics, MANPRINT, test, safety, software metrics, and independent verification and validation. All lead functional personnel in the Army team were active members of the IDT and participated in assigned CE development teams.

Three representatives of the Active Army—one captain and two sergeants—were permanently stationed at the IDF to provide on-site, real-time input to the IDT on questions concerning Army doctrine and tactics. They also provided an “on-the-scene” situational awareness for the Training and Doctrine Command (TRADOC) and the user community. To fulfill this role, they served as CE team members wherever their input and influence could be most effective.

Additional user participation is provided by User Exercises. These exercises are performed following the completion of each of seven software spiral builds into which the software development effort has been partitioned. In each User Exercise, a team of experienced active duty soldiers performs tactical exercises designed to test the increasing functionality of the software. These User Exercises provide iterative user feedback throughout the software development process and help ensure the resulting software will meet the training needs of the Army.

During the early months of the contract, IBM held three off-site meetings of all personnel involved in the CE teams. At these meetings, team missions and CE ground rules and operating procedures were presented. The principles on which the teams were organized included empowered multidisciplinary teams, a high level of user involvement, and life cycle product ownership. A hierarchy of processes was detailed, describing the operation of all levels of the organization from the program office, down through the CE teams, sub-teams, and working groups. These processes covered such areas as processing contract baseline change requests, generation and delivery of contract data, and day to day execution of the CE team activities.

The CE team missions gave them responsibility to design, develop, integrate, test, and deliver their assigned portion of the system. That is, teams were to produce the design and all test and support documentation for their products. They were to be self-managed and empowered to the extent allowed by the contract requirements and the program constraints.

In addition to the CE teams, working groups were formed to address certain areas that affected all CE teams. These working groups, in contrast to the multifunctional CE teams, were composed of members who had a functional interest in the working group's area of concern. Examples of working groups included the Software Working Group, which was responsible for ensuring that the software development processes guaranteed

training effective software, and the Data & Models Working Group, which was responsible for identifying the set of models and associated data for use throughout the CCTT.

Participation in the IDT CE teams and working groups was accomplished in several ways. The most visible was by the routine attendance of all team members, including the government functional and user representatives, at the regularly scheduled team meetings. This regular attendance was facilitated by the collocation of all participants. In addition, all members were linked by e-mail and access to the Contractor Integrated Technical Information Service (CITIS). This high degree of interaction allowed the IDT to function as a close coupled organization of both the contractor and the government team members.

Most literature on CE suggests formal reviews in a program can be reduced because of the increased communication between the contractor and the government. This was not directly evidenced in the CCTT development effort. In this program, separate formal design reviews were held for the software and hardware portions of the system. For software, a series of In Process Reviews (IPRs) replaced the formal PDR and CDRs. These IPRs are held for each software module and address, successively, the requirements, the high-level code, and the low-level code. While these reviews are still formal in the sense that government approval was required to successfully complete them, they are more in line with CE principles by allowing review of the software to be accomplished through a nearly continuous interaction of all affected personnel.

The more traditional approach of holding a formal PDR and CDR was selected for the CCTT hardware. Retention of these reviews allowed the government to use them for two purposes. The first was to provide a formal mechanism for government approval of the hardware design. The second purpose was to provide a forum in which the hardware design could be presented in a top-down manner to the TRADOC representatives present who had not had the benefit of participation in the CE design process.

The CE process demonstrated an impact on the cycle time for government acceptance of Contract Data Requirements List (CDRL) item deliveries. Because the process for developing the contract data included participation by the government team members, who are also responsible for accepting the delivered data items, there was a reduction in the time required for review and acceptance of the delivered data. The

situations where this did not occur generally resulted from conflict between achieving CE team consensus on what is acceptable data and meeting contract requirements for on-time delivery.

As part of STRICOM compliance with the DoD Continuous Acquisition and Life-Cycle Support (CALS) initiative, the SOW for the CCTT program included a requirement that the contractor implement a CITIS. In preparing the contract SOW, the government placed great confidence in the ability of the CITIS to perform in two areas. The first area was the use of the CITIS as the vehicle of choice for delivery of contract data. The second was as a tool for government access to contractor data, both the data being prepared for submission as a CDRL item and contractor data for which formal submission was not specifically required by the contract. Because CITIS was imagined to allow access to this last area of contractor data, the CDRL was scrubbed thoroughly to remove any requirements for documents whose data was envisioned to be available through the CITIS.

In the CCTT program, the implementation of the CITIS fell short of meeting both roles. Early in the program, the difficulties that had to be addressed included local area network speed, capacity, and connectivity problems. Once these were resolved, it became apparent that even more difficulties resulted from the desire to control access to data and network systems, on the part of both the government and the contractor. In some cases, the program resorted to the delivery of hard copy data to circumvent the CITIS altogether. These difficulties in the CCTT program highlighted the fact that much work for both the government and industry remained to be done to define and implement a successful CITIS.

As is evidenced in any human endeavor, the implementation of CE in the CCTT development process evolved as the work progressed. Three changes that occurred in the CCTT program dealt with the role of the government in the CE teams, the balance between meetings and individual work time, and the management visibility of problems in the program.

Early in the program, a PM CATT memorandum firmly placed the responsibility for delivering a quality training system to the field on the government team members. This they were to do by full participation in the IDT CE teams. Over time, however, government team members felt under increased pressure to make design decisions "on the fly" in team meetings. This perceived shift in the responsibilities of the government

members caused them to draft a formal set of guidelines for their role in the CE teams. This set included 14 specific roles, fully half of which addressed the role of improving communication, within and between CE teams, and between contractor personnel and both the PM Office and the user community. The remainder of the roles stated the government's responsibility to review and accept the design, ensure quality products, and evaluate contractor performance.

Another change to the CE process adjusted the balance between mandatory attendance at CE team meetings and time for individual labor. In establishing the CE approach, mandatory attendance at CE team meetings was required as a way to ensure participation by all. Over time, progressively more working groups and standing meetings were scheduled. As many functional personnel served on multiple CE teams, this increase in the number of meetings quickly began to prevent them from accomplishing individual work. During the second year of the program, a Process Action Team (PAT) was formed to address a growing dissatisfaction with the CE process. While the PAT addressed many issues, the one concern it acted upon was to readjust this balance between attending meetings and accomplishing individual work.

Another adjustment of the CE process occurred when it became apparent that issues affecting more than one of the CE teams and conflicts between teams were not receiving sufficient management attention. Therefore, weekly focus meetings were established at both the lead engineer and program office level to provide a forum for a nearly real-time identification and resolution of these issues.

Concurrent Engineering was implemented in the CCTT program in response to the need to create a strong user focus. The CCTT is a complex training system whose primary purpose is changing collective human behavior. Concurrent Engineering was implemented by multifunctional teams composed of both contractor and government members who are empowered and self-managing within the bounds of the contract requirements and program constraints and who are responsible for their products throughout the life of the program. Difficulties were experienced in adapting CE processes to CCTT development and in developing a CITIS to support the CE environment. However, in spite of the difficulties, CE proved to be a useful tool to increase communication among all functional elements and aid in successful program execution.

Persons Interviewed: Mr. Mike Edwards, Project Director, CCTT, AMCPM-CATT,
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Mr. Kent Brookins, Project Director, CCTT, AMCPM-CATT,
DSN 960-4333

Interviewed By: Mr. John Wheeler, AMXIB-P, DSN 793-4619

3. AH-64D LONGBOW APACHE HELICOPTER

The AH-64D Longbow Apache is a product improvement to the AH-64A Apache to enable this upgraded airframe to fire radar frequency guided Longbow Hellfire missiles. The total Longbow system significantly improves the adverse weather fighting abilities of the AH-64A, provides true fire-and-forget capability, and increases target acquisition efficiency. The AH-64D development program is an Acquisition Category ID (ACAT ID) upgrade to an existing system. The program was near the end of EMD when this case study was written.

McDonnell Douglas Helicopter Systems (MDHS), in Mesa, Arizona, was the prime contractor for the airframe upgrade and system integration efforts. They were responsible for the design and production of the upgraded aircraft. The \$621 million development contract began in August 1988. Since this program began before Concurrent Engineering (CE) and Integrated Product and Process Management (IPPM) were development strategies accepted within DoD, there are no contract requirements for their use.

MDHS's desire to improve aircraft performance, reliability, and maintainability; decrease production and life cycle support costs; incorporate MANPRINT improvements; and accommodate future subsystem growth led to the use of Integrated Product Teams (IPTs). At its own expense, MDHS formed eight component-focused IPTs (one for each subsystem under redesign) with a high-level IPT to serve as an overall system integrator. Each subsystem IPT had members from all functional areas. Similarly, the Integration IPT included members from the subsystem IPTs with other functional area members as required. In cases of purchased subsystems or components thereof, the component supplier also became a team member. Subsystem teams met as needed, while the integration IPT met weekly. MDHS made agreements with suppliers whereby they would be guaranteed production contracts if they achieved a design that met MDHS's performance, cost, and reliability goals.

Because the contractor self-funded the redesign efforts, the government did not participate actively on the IPTs and did not make any changes to the traditional oversight

structure or methods. The contractor used Unigraphics computer-aided design (CAD) systems to create and transmit designs between team members and between teams. Off-site suppliers received CAD designs via modem using the Initial Graphics Exchange Standard (IGES) format data files. MDHS could use this capability to send CAD files to some government agencies, such as the Military Traffic Management Command, but it could not do the same to the Aviation and Troop Support Command or the PMO because they lacked compatible technology. The CAD system was used to create an "Electronic Development Fixture," in which designs could be analyzed for physical interfaces and tooling development.

Each IPT had the power to make its own decisions regarding its subsystems if those choices fell within the existing budget. Each team bucked out-of-budget decisions up the chain. First, they established their own design requirement targets and goals and then created and evaluated design alternatives via trade studies. At decision points the team members voted on each design alternative using a pre-established set of prioritized functional area "weighting factors." For example, weight may be more important than cost. The members added the points for each alternative, and the highest totaled alternative won. It was up to the Integration IPT to decide between alternatives that affected multiple components or IPTs.

The results of MDHS's use of CE/IPPM and IPTs have been impressive. Component redesign has led to a weight reduction of 246 pounds per aircraft, a design-to-unit-production-cost reduction of \$139,000, a maintainability improvement of 44 percent, and a reliability improvement of eighteen percent.

As stated previously, since these MDHS teams engaged in self-funded efforts the government did not participate with them. The government saw the results at design reviews and program progress reviews, but no government personnel attended team meetings. MDHS felt that it could be difficult to integrate government personnel into future IPTs but that the problem rested more with government managers than with working level personnel. Government managers may not want to relinquish control of their functional area decisions to an empowered team independent of their control. All too commonly, government workers lack the empowerment to make decisions.

In the Longbow example, MDHS housed all team members in one physical location. Even subcontractors and suppliers had to send on-site representatives. Even so, the team members were not necessarily collocated in a common work area, and even a

small amount of separation created some communication problems. MDHS felt that the government should participate on these teams in its role as the customer; however, that would require physical collocation to the contractor facility. An alternative would be to use the Defense Plant Representative Office (DPRO), in its role as the on-site government agency, to serve as government customers on the contractor IPTs. This would require the system PM to vest decision authority with the DPRO and likewise the DPRO to inform the PM of program status constantly.

MDHS was not sure how the government would participate in the IPTs other than as the customer. In that capacity, the government would look at the design at various checkpoints within the IPT activities, rather than remaining continually and constantly involved. MDHS also was not sure how work assignments might be split between the contractor and government team personnel. Finally, MDHS was not sure that all government functional areas needed to be or should be represented on the IPTs. A suggested approach was to have one or two "generalists" on each IPT who could address multiple functional areas and overall program issues.

MDHS did have an earlier trial experience with IPTs on another program, but this was MDHS's first attempt at using multiple, commodity-oriented IPTs with a hierarchical structure. MDHS felt it was weak in the area of CE/IPPM/IPT training. In the Longbow case, the only training team members received was from several corporate policy manuals; the rest was oral. It is interesting that the parent company, the McDonnell Douglas Corporation, does have an IPT training program, along with assessment criteria for division certification. The corporation has four levels of IPT certification. MDHS received certification at the lowest level (Level 1). A weakness in the area of policy and training documentation is all that kept the company from a Level 2 certification. No division within the McDonnell Douglas Corporation has yet achieved Level 4 status. The Longbow teams gathered some lessons learned from MDHS's first IPT attempt.

MDHS intended to make greater use of IPTs in future contracts. Notwithstanding the absence of a quantitative cost/benefit analysis, the company believed that it definitely cost more to use CE/IPPM than traditional serial development methods. It was quick to point out however, that the improvements in production costs, maintainability, and reliability, coupled with the reduction in development time make CE/IPPM a favored business strategy. Indeed, MDHS could not have performed the redesign and still met production start dates without CE/IPPM.

Persons Interviewed: Mike Columbo, MDHS, (602) 891-2359

Jim Collier, Longbow PMO, DSN 693-5609

Ron Trejo, DPRO, (602) 891-3709

Interviewed By: Tom Schneider, AMXIB-P, DSN 782-7794

4. M6 SMOKE GRENADE DISCHARGER

The M6 Discharger is a smoke grenade launcher with independently addressable tubes. Its designers made certain that it has no radar signature in preparation for a new generation of host vehicles where stealth is important. The M6 is a new, Acquisition Category IV (ACAT IV), type classified system. Since no deployment requirements existed when the development was completed, the Army shelved the Technical Data Package (TDP) for future production. This program was in EMD when this case study was written.

The Army awarded the EMD contract to the Brunswick Defense Corporation, Deland, Florida, in September 1990. The Edgewood Research, Development, and Engineering Center (ERDEC) awarded this contract several years before it started using IPPM teams. There was nothing in the contract different from the usual government oversight provision included in the CDRL or other schedules.

Shortly after ERDEC changed to full-time team organization, Dr. Vervier, ERDEC Director, attended a regular meeting at Brunswick, with the ERDEC team. He explained how ERDEC planned to use IPPM teams and told Brunswick he considered them part of the IPPM team. Apparently, Brunswick was very receptive to the idea because it really became part of the team.

Army IPPM team included a project leader and 10 members who represented the interests of the combat developer, quality, producibility, testing, and logistics communities. Functional organizations and soldiers participated part time or as needed. The contractor did not form an IPPM team as such; however, selected contractor personnel worked with ERDEC team members as full team members.

The Army team used a variety of icebreakers. The sense from the interviews for this case study was that just about anything that helped the team to be acquainted, and was in good taste, was fair game for ice breaking. The team established its rules of conduct early, including procedures for teaming, a mission statement, how decisions were

to be made, and how meetings would be conducted. Training started early and continued to the point that team members felt it should stop so they could proceed with their work. In retrospect, the Project Leader thought it was advisable to insist on intense training—it probably helped the team to function together better.

Written, telephonic, and personal contacts were very frequent between the team and the contractor. Personal contacts did occur according to set schedules. Both groups traveled between sites extensively. Nothing was ever just “thrown over the wall” by either group. Electronic mail was not available between the two groups, but ERDEC members used it extensively among themselves. There was never any rejection of CDRLs or ideas because “it just isn’t right.” Instead, written and oral communications explained what the government needed and why. Most written or telephonic messages and personal discussions included suggestions on how to meet these needs, making the contractor part of the CE team.

The project leader said the team worked because everyone knew about everything that was going on. There was constant contact with the contractor and between team members. The team defined its primary role as being helpful to the contractor while avoiding an adversarial relationship with him.

Top management at ERDEC encouraged off-site team meetings if the team members supported having them. The team tried all sorts of innovative ideas: team lunches, team dinners, and team activities such as bowling a few games during working hours to help the team function. With management’s commitment, the team felt free to do what would work for them.

Before the teams formed, each functional discipline had a priority to get the project finished on schedule, but the disciplines’ priorities always differed with one another. When people joined the team and helped to decide issues, including priorities, they were able to keep the project completion—type classification of the Discharger—in mind. They modified individual concerns with overall project concerns. This behavioral change spread quickly through the team. The Project Leader could not recall even one experience with member incompatibility. He added people to the team, and they fit in very well.

For example, the Quality Assurance (QA) representative made a special effort to develop a good relationship with the Defense Contract Administration Service (DCAS)

representatives at the contractor's plant. This relationship helped both the team and the contractor.

One issue, never addressed satisfactorily, was how to handle the team when the project concluded and the team had no new project to undertake. The team just separated somehow without a prearranged plan. Downsizing at ERDEC, coupled with chance, seemed to drive the situation. Typically, another team leader with an active project needing a new member looked for a project that was ending and acquired the skills needed from a separating team.

Person Interviewed: Tom Hoff, Project Leader, SCBRD-END, DSN 584-5626

Interviewed By: Bud Fox, General Engineer, AXMIB-P, DSN 782-7815

5. HEAVY ASSAULT BRIDGE

The Heavy Assault Bridge (HAB) provides Military Load Class 70 vehicles the capability to cross 24-meter gaps (26-meter bridge). The base for the HAB is an Abrams tank chassis. The system consists of a bridge and launch mechanism mounted on an overhauled, converted Abrams chassis. The HAB is a Nondevelopmental Item (NDI) Integration item and is an Acquisition Category III program. The HAB program is under the direction of the PEO, Armored System Modernization, and is managed by the Product Manager, HAB.

The HAB was in the EMD phase when this example was written. The EMD was in two parts. In EMD I, three contractors—BMY, General Dynamics Land Systems (GDLS), and Southwest Industries—built two prototypes each for competitive evaluation. The Army selected the GDLS concept for the EMD II phase and awarded the EMD II contract in January 1994.

The RFP for EMD II did not contain requirements or incentives for use of the IPPM management approach. The RFP did include explicit requirements for program reviews and contract deliverables. GDLS did not try to negotiate any changes in the number of reviews or deliverables. GDLS began to use the IPPM approach in its organization for the EMD II program, but this was not a requirement of the contract.

The HAB PMO organized its staff to operate in an IPPM mode with GDLS. The PMO had a team of 13 full-time people dedicated to the HAB program. Five of these—the Product Manager, secretary, chief engineer, logistician, and engineer—were on the

PMO core staff. The remainder of the team included full-time matrixed personnel from the following disciplines: logistics (4 persons) and one each from software, contracts, quality, and cost. Other full- and part-time matrix personnel contributed as needed. The Engineer's School represents the user. The Engineer's School had a representative at all the monthly program meetings and other major reviews and demonstrations. A user jury, made up of Engineer's School personnel, evaluated the design as it progresses.

The basic role of the government IPPM team was the same as that of any other PMO team. It was responsible for ensuring that the requirements of the contract—primarily cost, schedule, and performance—were being met. The HAB team differed in that it was reviewing designs and plans as they developed with the GDLS team. Team members provided immediate feedback, rather than waiting for periodic reviews and analysis of deliverables. This provided results that were more suitable to the government and avoided waste of time and money in pursuing approaches that would have to be changed later.

GDLS used an IPT approach to the HAB project. Permanent members of the GDLS IPT were functional element managers. For the HAB project, the functional elements represented were engineering, logistics, and manufacturing. Major subcontractors participated where appropriate. Major subcontractors for the HAB were MAN/Gutehoffnungshutte Gmbh, manufacturer of the bridge; Stewart & Stevenson, manufacturer of the hydraulic power unit; and Caterpillar, manufacturer of the stabilization blade. The Sterling Heights, Michigan, facility housed the collocated GDLS IPT. The functional element managers were responsible for execution of the contract. Their responsibility was largely organizational and administrative. They drew on people from their respective organizations as needed to perform the work. People with appropriate skills organized into subteams to focus on given parts of the design, which generally corresponded to the WBS. This breakdown could have been at the system, subsystem, or detail level. The GDLS facility held the team meetings in which functional support personnel, government personnel, and, where appropriate, subcontractor personnel participated.

The ground rules for the government-contractor interaction were simple and clear. GDLS was responsible for providing a product that met the purchase description and for complying with the other contract requirements. The government was responsible for providing recommendations and evaluations as the designs and plans progressed.

Members of the government team took training courses in cost plus award fee contracting and in the use of PERT charts—skills required for the HAB program. GDLS personnel also received PERT chart training. The GDLS functional element managers who participated in the IPT received training to help them guide the IPT. The functional element managers served as the facilitators for the subteams. The members received extensive formal training for each software tool they used and learned the rest by participating in the subteams.

Government personnel participated regularly in the IPT meetings that GDLS held. This worked well because the HAB PMO was only about 2 miles from the GDLS facility. As stated above, subteams addressed various parts of the design as defined by the WBS. Both government and GDLS participation was tailored to provide the skill levels required for each subteam. There was as much commonality of personnel between the different subteams as possible. A subteam frequently began its work with a brainstorming session. Iterative meetings dealt with alternatives in increasing detail. The subteam walked through the design, created manufacturing process flows, positioned machines, and determined manufacturing process limitations. Parts were combined in various ways to eliminate or simplify plans for efficient manufacturing. Information from the meetings was captured in a producibility package. The package contained design constraints, manufacturing process limitations, logistics impacts, and design recommendations. The producibility package represented the subteam consensus and was the basis from which the designers, manufacturing planners, and logistics planners completed their work for that given portion of the design. The lengths of the meetings varied. The subteam met as necessary to complete its mission.

Analytical approaches served to develop data to aid in making decisions when the best choice was not obvious. The IPT applied an extensive set of Design for Manufacturability (DFM) tools at GDLS. The IPT used a PC-based CAD system with 3-dimensional modeling capability, sourced from Structural Dynamics Research Corporation. The CAD display was large enough for the members to see during meetings. The IPT used Variation Simulation Analysis (VSA), based on an original software package from Ford and enhanced by GDLS, and a Virtual Prototyping software package to model manufacturing processes. Virtual prototyping was used to model the part, fixture, machine tool, and working elements such as cutting tools and to evaluate tool paths and conduct end of tool modeling. GDLS could also simulate an entire factory

operation. The simulation included station requirements, throughput and fixturing requirements, and, possibly, line balancing.

The proximity of the HAB PMO to GDLS was a definite plus in achieving face-to-face interaction of personnel in the two organizations. Both parties used telephone and fax communications as well. The PMO had electronic access to the TDP and the logistic support analysis record in GDLS's database. Subteam meetings convened as necessary to develop the producibility package for each portion of the design. In addition, monthly government-GDLS meetings provided the opportunity to review progress and address problems on the entire program.

GDLS welcomed government participation in its IPT. It has not want to spend time and money developing designs and plans that will be found unsuitable to the government sometime later in a review. By working in the IPPM mode, there was very little problem reaching decisions that were acceptable to both GDLS and the government. When problems threatened an agreement, the approach was to perform more in-depth analyses to develop data on which to base a decision. Cost was the most frequent decision driver. Other factors that drove decisions included design requirements, schedule, human factors, and maintainability.

The GDLS Cost and Schedule Status Report (CSSR) tracked costs. Costs could be tracked to the fourth level of the work breakdown in the CSSR. Government personnel analyzed the CSSR carefully to identify overruns, underruns, and schedule variances and reviewed deviations with GDLS personnel. GDLS found the HAB cost and schedule requirements for EMD II were extremely challenging. GDLS decided that the IPPM approach was the only way that these requirements could be met. Using the IPPM approach in the HAB program, GDLS planned for significantly fewer Engineering Change Proposals (ECPs), fewer prototypes, and about half the total engineering person-hours required for a conventional approach.

Both the government and GDLS favored the IPPM approach taken on the HAB program. Government personnel had a chance to give their suggestions early as concepts developed, so it was easier to incorporate them. GDLS welcomed timely evaluation by the government to avoid expending time and money on approaches that could eventually be found unsuitable.

Persons Interviewed: Mr. Alex Bodner, Chief Engineer, HAB Program Management Office, DSN 786-7685

Mr. Gary Insona, Manufacturing Manager, General Dynamics
Land Systems, (810) 825-7672

Interviewed By: Mr. Walt Roll, Industrial Engineer, AMXIB-P, DSN 782-5617

6. BRADLEY FIGHTING VEHICLE SYSTEM

The Bradley Fighting Vehicle System family consists of the M2/M2A1/M2A2 Infantry Fighting Vehicle (IFV) and the M3/M3A1/M3A2 Cavalry Fighting Vehicle (CFV). The armored, fully tracked IFV and CFV provide cross-country mobility and vehicle-mounted fire power to mechanized infantry and cavalry units. The IFV/CFV vehicles are the complement to the M1 Abrams tank in the combined arms, close combat task force.

The effort to upgrade the A3 version was in EMD when this case study was written. The A3 is a major defense acquisition program under Acquisition Category IC (ACAT IC). November 1999 will mark the milestone III decision, production approval.

The Army awarded the \$240 million EMD contract to the United Defense Limited Partnership (UDLP) in May 1994. The contract did not require UDLP to use an IPPM approach.

COL Adams, Bradley A3 Associate Product Manager, was the nominal government IPPM team leader. Members of the government IPPM team were also government representatives on UDLP's Product Development Teams (PDTs). The team organized along functional lines with selected functional areas assigned to each PDT. For example, the government software engineer is a member of three PDTs. Most of the PDTs have seven to eight government team members. Each government member represented a functional area.

UDLP purchased the Texas Instruments (TI) Integrated Product Development Process (IPDP) and incorporated it into a corporate-wide policy. UDLP held a workshop, including government representatives, to introduce the process. UDLP used teaming in three levels:

- Level I—The Core Team provided general support to the A3 program. The A3 program manager led this team, which focused on the highest levels of program execution. The core team tracked overall program process and established policy.

- Level II—The Leadership Team guided the A3 program. This team consisted of representatives from all functional areas including the PDT leaders. The leadership team focused on the processes used by the PDTs to assure consistency and adherence to contemporary organizational effectiveness principles.
 - The System Engineering and Integration Team (SEIT) provided technical guidance to the A3 program. The SEIT consisted of managers of technical functional areas and PDT leaders. The SEIT leader was the A3 engineering manager. The team focused on technical issues that crossed PDT boundaries.
- Level III—The PDTs did the focused development work. All teams, except one, organized by product. A system integration PDT, organized along functional lines, was responsible for overall final A3 integration. Each team had a designated leader and multidisciplinary members to include UDLP, subcontractor, and government personnel.

Other teams, as needed, conducted special projects related to resolving an A3 issue. These special teams normally addressed a specific issue and then disbanded when the problem is solved.

The teams interrelated. Customer requirements drove the work through the system engineering PDT down to the other PDTs. The requirements decomposed into engineering tasks and specifications to be developed and integrated by each PDT. The system integration PDT handled the final integration. The SEIT handled program technical issues and the PDT leadership team handled process issues.

The government team met once or twice a month, depending on travel schedules. The purpose of these meetings was to update all team members on overall status of the program and to resolve any problems. The government's role on the PDTs varied. Sometimes the government team member was a leading contributor in problem solving, other times he/she just listened.

While the government team members traveled extensively, they did not attend every PDT meeting. The PDTs met every week, making it impossible for non-collocated government team members to attend every meeting. Occasionally a government team member visited UDLP for a reason other than a team meeting and attended a PDT meeting as well. Physical travel to UDLP was still the primary method of communication. The PMO was on the UDLP voice mail system. Plans were in place to incorporate the Joint Computer-aided Acquisition and Logistics Support (JCALS) system

and the Digital Storage and Retrieval Engineering Data System (DSREDS) into the Bradley program.

The government members believed they were adding value to the teaming process. Their contributions were in two primary areas: helping to understand the Army requirements and making team members aware of integration issues involving other teams. The involvement level of a government representative was totally dependent on personal commitment. Some became very involved while others just sat and listened.

Government team members did very little decision making. This was due to a concern about contractual issues and authorization to direct such issues.

Expenditure tracking was the primary task of each government team member. Each team member had several cost accounts, each divided by work breakdown structure. Each member took special classes to learn about cost accounting. Every month the government team member reported cost performance.

Person Interviewed: Mike King, Production Engineer, SFAE-ASM-BV-CP,
DSN 786-8668

Interviewed By: Frank Stonestreet, General Engineer, AMXIB-P, DSN 782-7799

7. COMPOSITE ARMORED VEHICLE PROGRAM

The Army Research Laboratory (ARL) proved the feasibility of using thick composites as structure and armor for combat vehicles. Subsequently, the Tank-Automotive Research Development and Engineering Center (TARDEC) conducted an advanced technology demonstration (ATD) of much greater scope. The Composite Armored Vehicle (CAV) ATD demonstrated the feasibility of a much more complex composite structure and, for the first time, addressed manufacturability, affordability, repairability, durability, ballistic performance, and effects of shock and vibration due to mobility over different types of terrain and weapon firing. The CAV was in the Concept Exploration and Development Phase when this case study was written. The Tank-Automotive Research, Development and Engineering Center (TARDEC) was using 6.3 funds to build the CAV Advanced Technology Demonstrator (ATD). The CAV ATD is a nonsystem specific 22-ton vehicle, using a 25mm medium caliber cannon and a 105mm XM35 cannon as force generators.

The Army awarded a \$50 million cost plus fixed fee development contract to the United Defense Limited Partnership (UDLP) in December 1993. The original contract

had only a brief coverage of IPPM. A subsequent contract modification included additional provisions for IPPM and funds for IPPM training. IPPM provisions flowed down to major subcontractors, including Hercules and Lockheed.

Four functional development teams managed the program. The personnel interviewed for this case study were government members of the Composite Structures Development Team (CSDT). The other three teams were the Armor, the Signature Management, and the System Integration Teams.

The CSDT was a true IPT, as it includes representatives from three ARL directorates, the Training and Doctrine Command (TRADOC), the Defense Contract Management Command (DCMC), the test and evaluation community, and UDLP. At this early point of its life cycle, the CAV did not have a Project Manager. Instead, the TARDEC Development Business Group headed the program. The UDLP efforts dovetailed with those of TARDEC. They established subteams for the upper hull, the lower hull, the crew compartment, and for ramps and joints.

The CAV ATD was among the first Army S&T programs to implement IPPD, and it was TARDEC's first implementation of the IPPM methodology. The IPT started in August 1993. The team wrote the RFP and staffed it within TARDEC. Industry comments were solicited. Members representing IPPM interests participated on the SSEB.

A TI system, known as IPDP, was the model for the IPPM methodology. First, top TARDEC and UDLP management tailored the TI package to the CAV. Next, intermediate managers tailored it and followed up by hosting a 2-day IPPM workshop led by TI in January 1995. The workshop paved the way for detailed tailoring of the package and implementation.

Army interaction with UDLP was frequent. Daily telephone calls, monthly co-chaired meetings, quarterly IPRs, and e-mail kept both parties in touch. The e-mail system has extra features that made it possible to transfer engineering drawings and various reports, manipulate them, and approve their status. Its virtual workplace capabilities were especially important in view of the 3-hour time separation between TARDEC and UDLP team members.

The lessons learned were as follows:

- The ground rules were consistent with those in the TI IPDP package, tailored to CAV. Both parties observed the rules and found no need to modify them.
- Cost and schedule impacts were considerations of every team decision. An advantage of the extensive teaming was that the government team could get a good handle on overfunded, underfunded, or previously unforeseen needs. Familiarity with contract provisions was essential.
- There was no conflict over proprietary information transfer and intellectual property protection.
- A small barrier to government-contractor teaming was UDLP's unfamiliarity in working with government personnel in such a close manner. The personnel interviewed believed that both parties would overcome this barrier as they become more familiar and confident with the terms of the contract.
- Easier prevention and elimination of misconceptions through teamwork was one big benefit of IPPM.
- The Army provided a prioritized list of government expectations in the contract and intended to update the list as the program evolved. This aided the contractor in understanding the government's needs and guided programmatic and technical trade-offs. The list helped reduce controversy in decision making.
- The Critical Design Review was accomplished without any substantive changes. The ease with which this process was conducted can be attributed to continuous coordination and problem solving that were byproducts of IPPD.

IPPM worked in this acquisition program because:

- Dissemination of the updated prioritized list of government expectations kept all team members current.
- Tailoring sessions included all stakeholders. Everyone participated to clarify misconceptions and correct flawed expectations.
- Tailoring sessions identified proposed scope of work and contract deficiencies or mismatches.
- The TI methodology was comprehensive (from start of work to contract closeout).

Persons Interviewed: MAJ R. Brynswold, AMSTA-TR-P, DSN 786-8718

Mr. Don Ostberg, AMSTA-TR-P, DSN 786-6133

Mr. Jeff Carie, AMSTA-TR-P, DSN 786-7715

Interviewed By: Mr. Ferenc Beiwel, AXMIB-P, DSN 793-7816

Appendix B
GLOSSARY

GLOSSARY

ACTD	Advanced Concept Technology Demonstration
ADAM	Area Denial Artillery Munition
ADS	Advanced Deployable System
AEDC	Arnold Engineering Development Center
AFMC	Air Force Materiel Command
AHWG	Ad-Hoc Working Group
AMSAA	Army Materiel Systems Analysis Activity
ARL	Army Research Laboratory
ASARC	Army Systems Acquisition Review Council
ATD	Advanced Technology Demonstration
BD&SG-C	Boeing Defense and Space Group-Corinth
BEST	Bids Evaluations Support Tool
CAD	Computer-Aided Design
CAIV	Cost as an Independent Variable
CALS	Continuous Acquisition and Life-Cycle Support
CAV	Composite Armored Vehicle
CCAWS	Close Combat Anti-armor Weapons Systems
CCTT	Close Combat Tactical Trainer
CDR	Critical Design Review
CDRL	Contract Data Requirements List
CE	Concurrent Engineering
CFV	Cavalry Fighting Vehicle
CITIS	Contractor Integrated Technical Information System
CONOPS	Concept of Operations
COST	Contracting Officer Support Tool
CPD	Concurrent Product Development
C _{pk}	Process Performance Index

CSDT	Composite Structures Development Team
CSSR	Cost and Schedule Status Report
DA	Department of the Army
DCAS	Defense Contract Administration Service
DCMC	Defense Contract Management Command
DFA	Design for Assembly
DFM	Design for Manufacturing
DFMA	Design for Manufacture and Assembly
DIS	Distributed Interactive Simulation
DoD	Department of Defense
DOE	Design of Experiments
DPRO	Defense Plant Representative Office
DSEG	Defense Systems and Electronics Group
DSREDS	Digital Storage and Retrieval Engineering Data System
DTUPC	Design for Total Unit Production Cost
EB	Electric Boat
ECP	Engineering Change Proposal
EFOGM	Enhanced Fiber Optic Guided Missile
EMD	Engineering and Manufacturing Development
ERDEC	Edgewood Research, Development and Engineering Center
ESG	Executive Steering Group
EVS	Electronic Visualization System
FEE	Functional Execution Element
FFDR	First Flight Design Review
FSD	Full Scale Development
GD&T	Geometric Dimensioning and Tolerancing
GDLS	General dynamics Land Systems
GM	General Motors
GOCO	Government Owned/Contractor Operated
GSTG	Government and Systems Technology Group
HAB	Heavy Assault Bridge
IDA	Institute for Defense Analyses

IDF	Integrated Development Facility
IDT	Integrated Development Team
IFV	Infantry Fighting Vehicle
IGES	Initial Graphics Exchange Specification
IMP	Integrated Master Plan
IMS	Integrated Master Schedule
IPD	Integrated Product Development
IPDP	Integrated Product Development Process
IPDS	Integrated Product Development System
IPPD	Integrated Product and Process Development
IPPM	Integrated Product and Process Management
IPR	Interim Progress Review, In Process Review
IPT	Integrated Product Team
ISR	Intelligence, Surveillance, and Reconnaissance
ITAS	Improved Target Acquisition System
JCALS	Joint Computer-aided Acquisition and Logistics Support System
JSF	Joint Strike Fighter
JSTARS	Joint Surveillance and Target Attack Radar System
JWCA	Joint Warfighting Capability Assessment
KC	Key Characteristic
KPP	Key Performance Parameters
LCC	Life Cycle Cost
LMVS	Lockheed Martin Vought Systems
LOI	Letter of Instruction
LPD	Landing Platform Dock
M&S	Modeling and Simulation
MDA	McDonnell Douglas Aerospace
MDHS	McDonnell Douglas Helicopter Systems
MDR	Milestone Decision Review
MGM	Materiel Group Manager
MICOM	Missile Command
MODAR	Modular Radar

MS	Milestone
MUSE	Multiple Unmanned Aerial Vehicle Simulation Environment
MWG	Management Working Group
NASA	National Aeronautics and Space Administration
NAVAIR	Naval Air [Systems Command]
NDI	Nondevelopmental Item
NGC	Northrop Grumman Corporation
NLOS	Non-Line-of-Sight
NNS	Newport News Shipbuilding
NVESD	Night Vision and Electronic Sensors Directorate
ODTSE&E	Office of the Director Test, Systems Engineering and Evaluation
OIPT	Overarching Integrated Product Team
OPTEC	Operational Test and Evaluation Command
ORD	Operational Requirements Document
OSD	Office of the Secretary of Defense
PAT	Process Action Team
PDA	Product Development Assessment
PDR	Preliminary Design Review
PEO	Program Executive Officer
PGM	Product Group Manager
PM	Program Manager, Product Manager, Project Manager
PMO	Program Management Office, Product Management Office, Project Management Office
POC	Point of Contact
PRIMES	Preflight Integration of Munitions and electronics systems
PRR	Production Readiness Review
QA	Quality Assurance
QFD	Quality Function Deployment
RFP	Request for Proposal
SADARM	Sense and Destroy Armor
SAVE	Simulation Assessment Validation Environments
SEIT	System Engineering and Integration Team

SOW	Statement of Work
SPC	Statistical Process Control
SPO	System Program Office
SSEB	Source Selection and Evaluation Board
SSR	Software Specification Review
STOW	Synthetic Theater of War
STRICOM	Simulation, Training, and Instrumentation Command
TARDEC	Tank-Automotive Research, Development and Engineering Center
TDP	Technical Data Package
TECOM	Test and Evaluation Command
TI	Texas Instruments
TIWG	Test and Integration Working Group's
TOW	Tube Launched Optically Tracked Wire Guided
TPIPT	Technology Planning IPT
TQC	Total Quality Control
TRADOC	Training and Doctrine Command
TRR	Test Readiness Review
UAV	Unmanned Air Vehicle
UDLP	United Defense Limited Partnership
USACOM	United States Atlantic Command
USAF	U.S. Air Force
USAIS	U.S. Army Infantry School
VDC	Vehicle Development Center
VM	Virtual Manufacturing
VP	Virtual Prototype
VR	Variability Reduction
VSA	Variation Simulation Analysis
WBS	Work Breakdown Structure

Appendix C
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13. ABSTRACT (Maximum 200 words) To help the Office of the Director Test, Systems Engineering and Evaluation (ODTSE&E) in its efforts to conduct Integrated Product and Process Development (IPPD) case studies, the Institute for Defense Analyses (IDA) searched the open literature and the World Wide Web for examples of IPPD implementation. This document summarizes these examples of (IPPD) implementation within the Department of Defense (DoD) program offices and defense and commercial industry. These examples show numerous successes with various facets of IPPD implementation. Different examples use different terms to describe the basic IPPD principles, but the message is still the same, involving the customer and the right stakeholders early, focusing on the life cycle, and developing products concurrently with their related processes all contribute to producing products faster, better, and cheaper. These examples are presented here for ODTSE&E to consider as candidates to expand into case studies.				
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